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THE ST. LOUIS WATER WORKS.

I. Historical.

By M. L. HOLMAN, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read March 7, 1894.*]

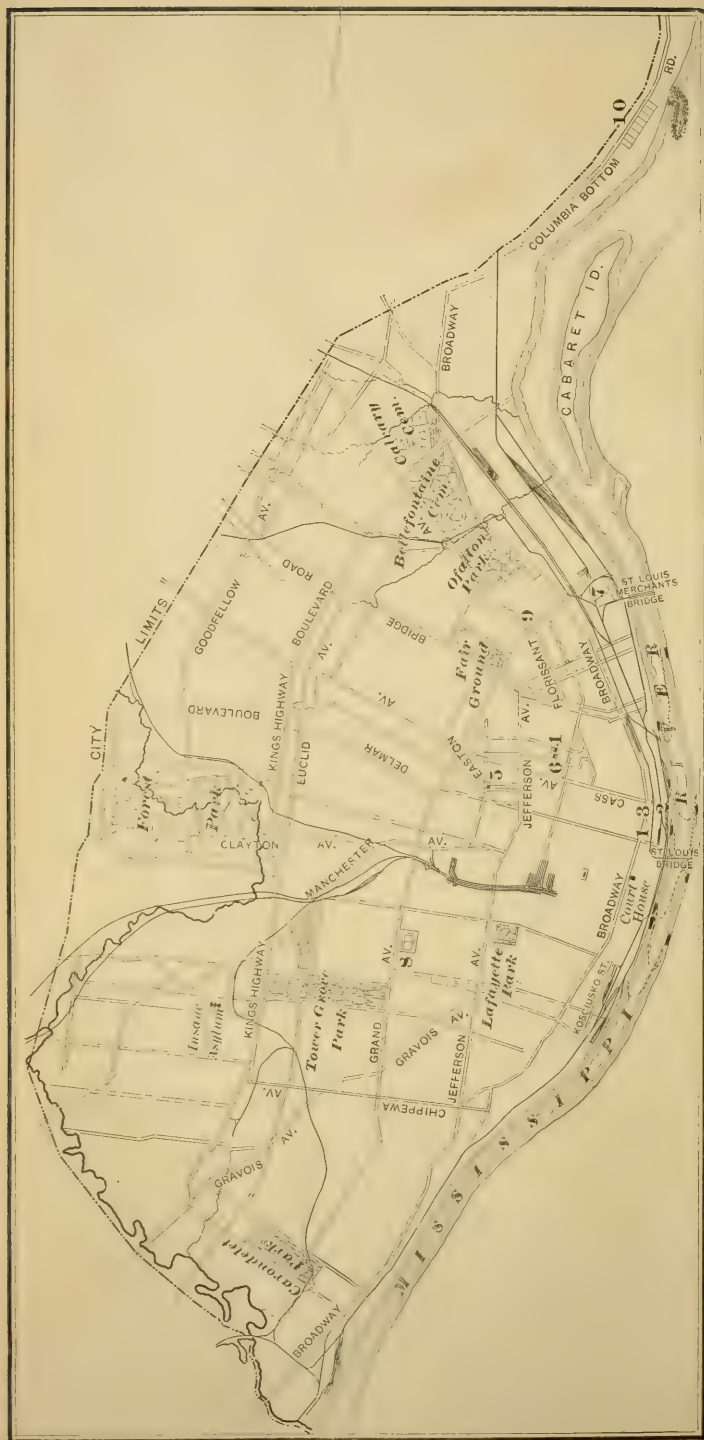
In opening the series of addresses on the St. Louis Water Works, I will give, as my contribution, what history I have been able to collect from public documents and other sources.

In the year 1829 the city of St. Louis contracted with Messrs. John C. Wilson and Abraham Fox for the building and operating of a water works to supply "clarified" water for a term of twenty-five years; the works to belong to the city at the expiration of the contract.

This contract gave the contractors the exclusive right to supply water for public and private purposes, the charges being limited to \$20 per year for families and \$100 per year for hotels and manufactories. The city further conceded a bonus of \$3,000 cash on the completion of the works; a lot of ground 40 feet by 125 feet on the river bank and a half acre of ground for a reservoir site.

In 1830 the city purchased of William H. Ashley a lot of ground 170 feet by 160 feet on the "little mound" located at the corner of Ashley and Collins Streets for a reservoir site, and a lot 250 feet by 250 feet from the U. S. Government for a pumping site.

* Manuscript for this series of papers received from November 24, 1894, to January 19, 1895.—*Secretary Assn. Eng. Socs.*



CITY OF ST. LOUIS.—SKELETON MAP.

1. Little Mound, Ashley and Collins Sts.
2. Site for Pumping Station, foot of Smith St.
3. Reservoir, Bates and Collins Sts.
4. Benton St. Reservoir.
5. Park.—Former site of Temporary Reservoir,
Gamble St. near Garrison St.
6. Reservoir built 1854-5.
7. Bissell's Point Works.
8. Compton Hill Reservoir.
9. Standpipe of Bissell's Point System.
10. New Water Works at Chain of Rocks.

The contractors were to supply, free of charge, water to twelve fire hydrants, the hospital of the Sisters of Charity and a fountain on the grounds of William Ashley. The water was to be distributed through cast-iron pipes laid not less than $3\frac{1}{2}$ feet under ground. Water was to be delivered to the reservoir in one year and to the hydrants in eighteen months.

But little progress was made under this contract, notwithstanding the fact that the then mayor, Daniel D. Page, gave his private note to secure payment for water pipe ordered of Vanleer & Company. The contractors were forced by want of capital to suspend work, and the city was forced into a new contract, dated April 2, 1831, with Mr. Fox, in which he was released from all the conditions of the first contract except the fountain for Mr. Ashley; this fountain being a part of the consideration in the purchase of the reservoir site. In this contract the city agreed to assume three-fourths of all expenses and take charge of and complete the works.

The city borrowed \$25,000 in 1831 in order to proceed with the works. The supply of water was in all probability begun in the fall of 1831. Old reports refer to this date, but positive statements of water supply do not appear until the summer of 1832.

The early management was under the care of a committee of the City Council, and it appears that the work was carefully conducted. Until 1847 the plumbing and all work connected with the supply of private houses was conducted solely by the city, which manufactured for that purpose its own lead pipe and fixtures.

In July, 1835, the city purchased the interest of Mr. Fox in the works, paying \$18,000 therefor.

The total cost of the works to this time was about \$54,000, not including interest-bearing notes given in pay for pipe. The city then became sole owner of its water works.

The first pumping engine was built for the works by Francis Pratt, of Pittsburg. The steam cylinder was 10 inches diameter by 4 feet stroke. The pump was double-acting, and the piston was 6 inches in diameter and of 4 feet stroke. This engine proved to be a failure and was replaced by two rotary pumps which the city had purchased for fire engines. These rotaries were set up in a small building at the foot of Smith Street. The water was delivered into a reservoir at the corner of Bates and Collins Streets. This was the first reservoir used by this city. The reservoir was 62 feet by 55 feet, with a depth of 15 feet. The flow line was 90 feet above the city directrix. The walls were of masonry, lined with brick, and the bottom was paved with brick on a tight plank floor.

These facilities supplied sufficient water for ordinary uses, but failed

to give an adequate fire supply on account of the smallness of the distribution pipes. Although a settling basin was constructed near the engine house it does not appear to have been used, all evidence going to show that water was pumped direct to the city reservoir without settling.

In 1836 a new pump main 10 inches in diameter was laid, and in 1839 a new engine was started. It was direct-acting. The steam cylinder was 13 inches and the water cylinder 13 inches in diameter, and both were of 6 feet stroke.

In 1838 a new pump main 12 inches in diameter was laid and a new reservoir was decided upon, but the project was abandoned.

In 1845 a new reservoir was erected on the site of the old one. It was a wooden tank 100 feet square by 12 feet deep. The walls of the old reservoir were used as a support for the middle part of the bottom, and a dry stone wall was laid up to carry the edges of the tank. The tank rested on these walls and on intermediate posts. It was built of oak, framed and spiked, and the seams were caulked with oakum.

The use of both reservoirs continued, the upper one being used for supplying the higher districts. It seems that the city was at that time divided into two districts.

After a few years' use of the double system, the old, or lower level, reservoir was abandoned and the distribution was thrown onto the upper reservoir. By the year 1849 frequent repairs to the wooden tank became necessary, and in 1852 it was abandoned.

In 1846 the superintendent of the works first suggested that the supply of water for the city be drawn from the Meramec River. The discussion on this question continued until 1854, when the then superintendent reported against the scheme.

In 1846 the third pumping engine was erected. The machine was of the crank and fly-wheel type. The steam cylinder was 20 inches diameter by 7½ feet stroke. The pump was double-acting, 15 inches diameter and of the same stroke as the steam engine. The engine gave trouble on account of bad foundations, and in 1847 it "laid down" and was rebuilt. In 1852 the fourth engine, costing \$25,000, was erected; steam cylinder, 26 inches diameter by 10 feet stroke; pump, double-acting, piston, 22 inches diameter by 10 feet stroke. It was originally started as a condensing engine, but the condenser was abandoned in 1852.

In 1847 the third reservoir was begun. This was the old Benton Street Reservoir. It was 250 feet square, with a working depth of 15 feet. Elevation of flow line, 115½ feet above datum, cost \$74,000 (approximate). The pump main to this reservoir was a 20-inch cast-iron pipe and was laid up Mullanphy Street. The reservoir was finished in 1849. It was provided with a sloping bottom and a system of flushing

sewers for the purpose of removing sediment, but the scheme was a failure.

In 1854 the fourth reservoir was begun, the claim being that the flow through a large reservoir would be at a low velocity, and that the sedimentation would be correspondingly good. This reservoir had a bottom laid out in the shape of a nest of very flat inverted pyramids, the bottoms being provided with valves, and a system of flushing sewers. The reservoir was 527 feet by 237 feet, with a depth of $47\frac{1}{2}$ feet. The cost was about \$200,000 and water was first pumped into it in 1855. This reservoir gave the city a great deal of trouble; the cleaning scheme proved a failure, and the walls required constant repair and careful watching. The water line was carried 138 feet above datum. This reservoir, after many vicissitudes, was finally abandoned and removed, and the site divided up, part being retained for public purposes and the remainder sold.

During the building of the new works, or from 1867 to 1872, a temporary reservoir on Gamble Street near Garrison Avenue was built and was used in conjunction with the old reservoir. In 1867 the sediment in the old reservoir was twenty feet deep.

The fifth pumping engine, with steam cylinder 30 inches diameter, stroke 10 feet, pump double-acting, piston 22 inches diameter, stroke 10 feet, was put in to keep up with the demand for water. In 1858 a new pump main 30 inches diameter was laid up Cass Avenue, and the 20 inch main was turned in on the distribution system. The old pumping engines, Nos. 2 and 3, were sold for scrap in 1857, and the Benton Street reservoir was abandoned in 1855.

At the old pumping station an engine with steam cylinder $34\frac{1}{2}$ inches diameter by 10 feet stroke, and double-acting pump $28\frac{1}{2}$ inches by 10 feet stroke, was put in to keep up the supply during the building of the new works (1865-72). This old station, with its pumps and piping, was operated until 1871, at which time the Bissell's Point Works started. A breakdown at this High Service Station necessitated starting the Bates Street engines again, but on June 19, 1871, they were shut down for the last time.

This station was wrecked and the machinery sold at auction, and after its removal the location was used for a pipe yard. The property was subsequently turned over to the Harbor Department for wharf purposes.

This is briefly the history of the St. Louis water works from the time of their inception up to 1867, for the old works; and up to 1871 for such temporary work in connection with the old works as was necessary during the building of the new works.

The new water works date from 1863, when the General Assembly

of this State passed an act entitled "An Act to enable the City of St. Louis to extend the Water Works thereof and for other purposes." This act authorized the city to construct works to take water from any point on the Mississippi River and conduct it to the city. It also created a board of four commissioners, to be elected by the Common Council of the city, to carry out the provisions of the act. It further provided for an issue of bonds for the purpose of constructing the new works, limiting the amount to \$3,000,000.

The City Council, at its May session, 1864, passed Ordinance No. 5339, establishing and regulating the Board of Water Commissioners, in conformity with the general act of 1863. But, owing to general dissatisfaction, no action was taken under this ordinance, and, in January 1865, the General Assembly amended the Act of 1863, placing the appointment of the commissioners with the Governor of the State, who appointed Messrs. Dwight Durkee, Dr. Philip Weigel, N. C. Chapman and Stephen D. Barlow.

This board organized on March 18, 1865, and, on the 27th, submitted to the City Council the appointment of Jas. P. Kirkwood as Chief Engineer, which was approved.

On May 11, 1865, the Board directed the Chief Engineer to proceed with the surveys and plans for a system of water works. The plans and estimates were submitted on August 29, 1865, adopted by the Board October 6th and forwarded to the City Council for its action on October 12, 1865.

This scheme contemplated the location of the Low-Service works at the Chain of Rocks; the work to consist of a pumping station, settling basins and filter beds; the filtered water to be conducted by gravity flow in a conduit to Baden, and there pumped by the High-Service Plant to a reservoir to be built at Rinkels with a high water line 204 feet above datum; an auxiliary reservoir to be built on Compton Hill to furnish full supply for the southern part of the city. The works were designed for an ultimate capacity of 40,000,000 U. S. gallons per day. This scheme was rejected by the City Council in March, 1866. The Council recommended, after report by sub-committee, that the filter beds be abandoned and the works located at Bissell's Point.

During the consideration of this report by the Council, Mr. Kirkwood was sent to Europe to examine and report upon methods there in use for filtering water.

In April, 1866, the first Board of Commissioners resigned, and a second board was appointed. This board organized in August, 1866, with Geo. K. Budd as president and C. S. Solomon as secretary. In November of the same year it submitted to the Council plans for extending the old works, prepared by Freeman J. Homer, City Engineer.

In December, 1866, another plan was submitted, prepared by Mr. Kirkwood in accordance with the following :

Resolved.—That the Engineer be directed to prepare a general plan of works, founded on the following basis, to wit :

That the water be taken from the Mississippi River, in the neighborhood of Bissell's Point.

That settling basins be established there without the accompaniment of filtering works.

That a small storage reservoir be constructed on the City Commons.

And that the whole be arranged, so far as practicable, so as to admit hereafter of the convenient addition of whatever further works may then become expedient or necessary, and that the engineer be instructed to report the estimated cost of the works in question.

The plan reported by Mr. Kirkwood, in answer to the above resolution, is substantially the one upon which the new works were constructed.

In February, 1867, an ordinance looking to the enlargement of the old works and authorizing the issue of \$275,000 in bonds, was passed. In March, 1867, the Board of Water Commissioners made a demand on the Comptroller for the bonds, appointed Mr. Homer superintendent, and instructed him to proceed to carry out the plan proposed by him in November, 1866. This scheme fell through and no work was done. The report and plans were printed in the second report of the Board of Water Commissioners.

On March 13, 1867, the General Assembly passed an Act authorizing the issue of bonds to the amount of \$3,000,000 and appointing a new commission.

This commission, after it got into working shape, consisted of Geo. K. Budd, Alexander Crozier and Henry Flad, and under this board the works were built.

The Commission organized March 22, 1867, and on the 23d the former board turned over to them the old records belonging to the department.

On the 26th Mr. Kirkwood was requested to resume the duties of Chief Engineer from which he had been relieved by the former board on March 18th.

Mr. Kirkwood declined further service as Chief Engineer, and recommended Mr. Thos. J. Whitman for that position. Mr. Whitman reported for duty May 7, 1867.

Mr. Whitman was in favor of the Chain of Rocks location for the low-service works, adding his opinion to that of Mr. Kirkwood and all other engineers who had examined the situation carefully. He found, however, that the exigencies of the supply and the limitations of the law left but one thing to do, viz., to go ahead with the

work on the Bissell's Point plans. The works thus built, with which most of you are familiar, consist of an inlet tower, or intake, on the river bank at Bissell's Point; a low-service pumping plant; settling basins; a high-service plant; a stand pipe; large extensions to the old pipe system; and a storage reservoir on Compton Hill. These works, extended up to 1872 by the addition of two pumping engines, had a working capacity of about 32,000,000 U. S. gallons per twenty-four hours.

It must be borne in mind that all water furnished to the city is pumped twice; first, from the river into settling basins by the low-service plant; and second, from the basins into the distribution system and reservoir by the high-service plant.

In 1876, the city of St. Louis adopted a charter and changed its system of local government; the water works, with the exception of the collection of the revenue, being placed in the hands of a Water Commissioner, who acts as Chief Engineer and executive head of the department.

Additions to the high-service pumping plant were begun in 1881, and continued up to 1894. A new pumping station, complete, with pump mains and stand pipe being completed, making the total high-service capacity from 60-65,000,000 U. S. gallons per day (twenty-four hours).

To keep up the supply of water to the high-service plant, a temporary low-service plant was put in, having a capacity of 30,000,000 gallons per day. This plant, built on an inclined way, moves on wheels up and down the incline according to the stage of water in the river. The general scheme of this plant has been followed by the city of Cincinnati to afford temporary pumping facilities.

After several ineffectual attempts to secure the necessary legislation authorizing the extension of the low-service works, the City Council passed Ordinance No. 14212, approved September 7, 1887, establishing a low-service station at the Chain of Rocks. This station consists of an intake tower, an intake tunnel, a pumping plant and a system of settling basins.

The works are designed for a capacity of 100,000,000 U. S. gallons of settled water per day. Work on this plant is now nearing completion.

On December 26, 1893, Ordinance No. 17339 was approved, authorizing the further extension of the high-service plant.

The work on this plant has been started, but little, beyond the sub-foundation work, has been done. This plant is designed to furnish water to the districts of the city and county that lie at an elevation beyond the reach of the Bissell's Point works.

In closing, I will remark that it now seems that the city has got fairly to work along lines which, if followed, will insure to it an adequate supply of water, fulfilling all modern requirements.

II. Points of Interest in the Design and Construction.

By S. BENT RUSSELL, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read March 21, 1894.]

IN this paper I shall merely outline a few of the problems that were met in the engineering work, with the hope that they may prove of interest in connection with the other papers on the new water works.

Our first work was done on

THE NEW CONDUIT.

The two ends of our line were fixed at the old and new intakes. See Fig. 1.

Between these two points it was necessary to follow around a concave bend in the river so that the shorter line would, of course, be the closer to the bank. To secure the work in high water it was necessary to run the line along the edge of a terrace or berm known as the second bottom. As this conduit draws its water from the bottom of the new settling basins at the Chain of Rocks, and delivers it into the top of the old settling basins at Bissell's Point, there was not much choice in the matter of slope and elevation of the conduit.

The maximum flow line of the conduit is about four feet above the highest flood of the last twenty years and has a slope of 1 in 10,000, or about one-half foot per mile, which is somewhere near the slope of the Mississippi.

Near the old pumping works the line crosses low ground for nearly a mile, the masonry resting on a fill about five feet deep. There was some talk of using iron pipes over this stretch, but this idea was abandoned. A primary bank, raised to the elevation of the spring line of the conduit arch, was built and allowed to settle many months before placing the masonry and cover bank.

This primary bank rests on bottom land which is underlaid by quicksand some ten feet thick on top of the country rock. As soon as the cover bank was built its weight seemed to carry down the primary bank and masonry together. This settlement of the masonry amounted to from one to six inches, and was, I think, due to the displacement of the underlying quicksand; but that is a matter for discussion.

As the line crosses three important creeks, bridges were needed.

These were carried down to a rock foundation so that the conduit at these points is not allowed to settle.

THE CROSS-SECTION

of the conduit masonry is perhaps of special interest. In order that an empty tunnel in soft earth may have the greatest strength against distortion, its cross-section should be an ellipse with the major axis vertical. There are several practical objections, however, to making the height so great. We therefore cut the ellipse through the minor axis, remove the lower half and substitute an *inverted beam*. This bears the stresses in the arch the same as if the ellipse were complete. See Figs. 2 and 3.

If instead of the beam we had substituted a flat inverted arch resting on soft earth, the section would probably be somewhat distorted before the thrust of the inverted arch was balanced by the *passive* pressure of the earth behind the side walls.

As shown in Fig. 3, the section is only an approximation to a semi-ellipse, being made with vertical side walls and a full center arch. The bottom is designed to act as a beam, but is hollowed out in segmental form, as this gives an increased water way at slight expense. The outside of the side wall was carried up vertically so that the concrete might rest against the undisturbed earth in the walls of the trench.

About seven-eighths of the line was in cut. The conduit was everywhere covered with three feet of earth. All railroad crossings are bridged over so as not to rest on the masonry or cover bank.

Overflow weirs are provided at distances of about two miles. Man-holes are about one-fourth of a mile apart. Large chambers are arranged at each end and at each change of water section, so that cleaning machines can be put in, floated down and removed without difficulty. To permit this, there are, of course, no obstructions allowed in the waterway, which remains of the same form from end to end of the 11-foot conduit, and from end to end of the 9-foot conduit.

Before proceeding further with the plant itself, let us take up the subject of

ORGANIZATION

and methods of the engineer corps. The civil engineering force included four divisions: the conduit division, the river-work division, the basin division and the drafting division. Excepting the last-named, each division was composed of a division engineer, a field party and inspectors of contract work. There were three offices—one at Bissell's Point, one at the Chain of Rocks, and one, half way between these, at Baden. Each party was provided with teams for transportation.

To prepare for construction, preliminary surveys were made for

each piece of work. Frequent soundings and borings were made, to determine the elevation of the rock. Our experience taught that the evidence obtained from borings must be used with discretion. What is reported to be bed-rock often proves at a later date to be but a lonesome boulder. In important cases, therefore, trial shafts were sunk before the contracts were let.

To comply with the law, all important construction was done by contract let to the

LOWEST BIDDER.

Hence to obtain good work it was necessary to have the plans and specifications very full and complete. Our contracts might be divided into two general classes—*A*, where a lump bid is made for the whole work; *B*, where a bidder names a price per unit of measurement for each class of work and the value of the bid is determined by the engineer's estimate of quantities. Form *A* was generally used for machinery, buildings, etc., and Form *B* for earth and rock work, masonry, pipe lines, railroad tracks, etc.

When form *A* was used the greatest care was necessary in the preparation of plans and details, as alterations of plans generally caused extra expense to the city. Any losses caused by errors in these plans were borne by the city.

SPECIFICATIONS

were first drafted by the engineer of the division, checked over in the drafting department and revised by the principal assistant engineer. They were then submitted to the Water Commissioner, and by him laid before the Board of Public Improvements.

PLANS

were made by the draftsmen, checked over by the first draftsman and then by the engineer of the division including the work. They had then to be approved in order by the principal Assistant Engineer, the Water Commissioner and the Board.

All drawings are numbered and indexed in a card catalogue of the kind used for libraries. We have, I think, about 1,400 drawings catalogued. Field notes too are numbered and indexed in the same catalogue with the drawings.

In preparing our contracts, we endeavored to divide between the two parties to the contract the risks of unforeseen difficulties. We thus on the one hand avoided excessive prices due to contractor's risk, and on the other hand made it the contractor's interest to keep down the cost of the work.

After the contract was let, the only

SECURITY

the city had, was in the bond of the contractor. By retaining a percentage on monthly payments the security was gradually increased until the work was completed.

Under the law, the Board of Public Improvements can take no account of an individual contractor's actions in the past, and this condition has added considerably to the difficulty of obtaining good work. In the

EXECUTION OF CONTRACTS

rigid inspection was the rule. Inspectors were frequently located at shops, mills, quarries, etc. In the field, wherever a foreman was needed, there would be an inspector. All water-tight work and underground work was given special attention. From our system of letting contracts there was necessarily no consideration shown a contractor on account of low prices.

Effort was made to keep accurate accounts of all force and material used by the contractor.

Materials were tested when practicable. As the item of cost of cement was in the hundred thousands, especial attention was given to the tests of this material.

When a piece of work was completed

FINAL DRAWINGS

were made, showing it as actually built in detail, while records are kept showing all tests of material used, etc.

We will now return to the plant itself, taking up the

INTAKE AND PUMPING STATION.

The first work done was in making soundings of the river and borings in the shore, preliminary to designing the plant. Submarine borings in the rock were desirable, but were omitted as being too expensive. Before finally deciding on a tunnel, a prospect shaft, 90 feet deep, was sunk on the proposed line. This was accomplished with considerable difficulty, owing to the water encountered.

The problem of designing the intake was an interesting one. The low water channel was found about 1,500 feet from the shore. Between it and the river bank is bare rock bottom, showing projecting reefs at low water. The difficulties in the way of laying a pipe out to the channel were great. It was thought wiser to tunnel under the river.

The intake tower offered some interesting problems. Such a tower, with its gates, screens, etc., is by no means as easy to build in twenty

feet of water as a bridge pier would be. A masonry tower was decided on, and a suitable site on the rough rock bottom was selected by careful soundings. The tunnel was kept as near to the bottom of the river as was thought safe, so that in case of necessity compressed air could be used to check the inflow of water.

The question of lining the tunnel was discussed. While it was driven through solid rock and would not need any support, the large amount of sediment in the water to be taken, made a uniform and high velocity of flow quite necessary to prevent an excessive formation of sand bars. The section adopted is a circle 7 feet diameter inside of the lining. This will give 100 millions of gallons in twenty-four hours, with a velocity of about 4 feet per second. In case the tunnel becomes obstructed, it can be drained and cleaned. Both the river and the shore ends of the tunnel drain to a sump in a shaft on the river bank, and a short branch tunnel, controlled by a gate, taps this sump and drains to a large shaft in which pumps may be set.

There was some discussion as to the best location for screens to intercept the fibre in the water. Coarse gratings were put over the tower gates to stop large drift, but the fine screens were put in a chamber at the outflow end of the tunnel near the engine house, where they can be watched and frequently cleaned.

We started the tunnel under the river from the shore shaft on a rising grade of 1 in 200. For the first 600 feet our grade followed very closely the stratification of the limestone. Then the roof rock began to dip rapidly the other way. To keep to our plans we would have had to cut through this stratum. There were, however, indications of a wet seam above this layer of rock, and it was thought prudent to follow the trend of the rock. We did this, driving a 7 x 10 foot heading until we had nearly reached the end, when the rock dipped so rapidly that we were forced to cut through the roof layer. It was not until our heading was driven the entire length that we laid out the final grade for the brick lining. It was then decided to lower the axis of the lining so as to avoid cutting into the roof rock except at the channel end of the tunnel. This change of grade was quite expensive, but to have avoided it might have proved much more costly.

Although we stopped off large quantities of water in our working shaft, we still had a steady downpour of 50 or 60 gallons per minute in the shaft while we were driving the tunnel. About 1000 feet from the shore we crossed a fissure that poured about the same amount of water into the tunnel. There was a little seepage all along the line. The water gave us considerable trouble in lining the tunnel. At the fissure above mentioned, where there was a sheet of water pouring through the roof right across the tunnel, we prepared for the brick lining by putting in a

wrought iron shield curved to 54-inch radius, and provided with gutters and spouts to lead off the water. This shield was hoisted into position under the cataract and the brick arch carried through underneath it, leaving the shield concealed in the brick work.

In lining the tunnel we worked down the grade. Short pipes were laid through the wall where needed to relieve springs of water. When we had a long stretch of tunnel lined, and the water running along the invert had become troublesome, we built across the tunnel a brick dam provided at the base with a 6-inch outlet pipe and valve. Before starting a length of invert the valve was closed and the seepage allowed to accumulate above the dam. When the stretch of invert was ready, and the upper end of the tunnel was full of water to the top of the dam, the valve was opened and our reservoir emptied out. Two of these dams were built, and they proved very useful in storing the seepage water until it could be released without inconvenience.

IN DESIGNING THE INLET TOWER

at the channel end of the tunnel, account was taken of the enormous strains which might result from ice gorges resting on and wedging against the structure.

As a small base was desirable on account of the expense and difficulty of placing a large coffer-dam, the superstructure was given additional height and weight to increase the stability.

To increase the resistance against shearing, large anchor bolts were set, passing through the lower five courses of masonry, and reaching several feet into the rock ledge. As shown in Fig. 6, the up-stream end of the tower is formed into an ice-breaker. On account of the wide range in the stages of the river, gates were provided at different levels. At high water the lower gates will remain closed, and those which are more accessible will be used. The gates in the north chamber will generally be used, as, in case of their failure to shut, the gate in the party wall can be used to keep the water out of the tunnel.

The shore end of the tunnel empties through the screen chamber into the

WET WELL

from which the pumping engines draw.

In locating this part of the work, after sinking many bore holes and prospect shafts, it was found best to build at a point about 700 feet in-shore, where the excavation would be in more stable material. In the design of this plant the flood height of the river was again a factor. The engine pits, etc., must be proof against high water, and on the other hand the pumps must be little, if any, above the low water level. Hori-

zontal pumps would not seem appropriate under these conditions, and hence deep pits and vertical pumping engines had to be adopted.

The conditions of the pumping problem were these. The water must be delivered at a fixed elevation, to supply the settling basins. It must be drawn from an elevation depending upon the stage of the river.

There is some controversy as to the best arrangement for such a case, some contending that the water should be held back by means of gates, so that the pump will work under a constant suction lift, while others would allow the pressure in the suction to vary with the stage of the river so as to reduce the average lift. At the Chain of Rocks the pits and gates have been so arranged as to permit the use of either method. A wet well or fore bay is provided, in which the water may be allowed to stand at the level of the water in the channel of the river, or may be kept at the constant level of low water. Before the cheapest and best form of wet well could be agreed upon, it was necessary to consider whether the well should be built as part of the same structure as the engine pits, with only a masonry dam between them, or whether it was better to use a separate structure, as was finally adopted; whether the well should be rectangular or circular; whether there should be one or several, and whether it or they should be large or small.

In getting out the details, the design of

THE RETAINING WALLS

formed an interesting study. Allowance was made for the support given by cross-walls. Part of the overturning moment is balanced by the transverse strength of the masonry. In preparing the plan of the engine house we were limited by the great depth of the substructure. A rectangular building was inevitable, if we would have a solid foundation.

It was thought safer also to have the boiler-house independent on its own foundations, so that it might settle without distortion.

The delivery well, into which the engines pump, was located on rising ground in front of the pumping station where there was a good clay foundation for the masonry. Each engine is provided with an independent delivery pipe which spills into this basin. A free spill was given so that there can be no return flow when a pump is stopped.

THE BOILER HOUSE

was planned for a single row of boilers, as this arrangement is best for ventilation and light. The chimney, 6 x 150 feet in interior dimensions, is of brick. It stands on a separate foundation extending to ledge rock. Flues and steam mains are overhead. Considerable effort was made to

find an economical way of getting the coal from the railroad train into the furnace. What might be called the reservoir system was finally adopted, on the ground that it would be the most uniform in operation. By this plan all coal must be handled three times.

From the gondola car it is unloaded into the coal house. It is then shoveled, as needed, into iron charging cars, and from these into the furnace. The coal-house forms a reservoir so that the contractor can unload his cars as they come in, while on the other hand the coal passer has always about the same distance to go for his coal. This method gives a much more sightly stoking-room than is had where the coal is delivered directly in front of the boilers.

BUILDINGS

were made rectangular in plan, with tin roofs. The engine and boiler-houses were built with riveted steel roof trusses.

TRACKS

for coal-car handling were laid out with some care. There is a siding for loaded trains and one for empties. Another siding runs through a long coal shed for reserve coal, to be used only in case of strikes or other emergencies. A siding runs into the machine shop, and another runs into the engine house, so that machinery can readily be moved from one building to the other. Two forty-foot track scales are provided for weighing cars.

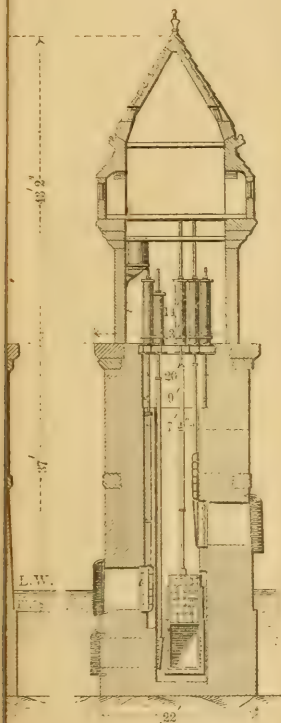
THE SETTLING BASINS

offered many interesting problems, and it will be hard to give a readable list of them in the short space which I have allowed myself. The first and most important question that came up was whether the basins should be designed for a uniform continuous flow of water or whether the water should be allowed to come to rest and be given a period of undisturbed settlement before it is drawn off into the conduit leading to the high-service pumps. By which plan should we get the best results with a given expenditure?

The difficulties in the way of arriving at the truth in this question were considerable. There was no way of comparing the two methods, on a large scale under similar conditions of sediment, etc.

A basin designed for the plan of quiet settlement or of *filling and drawing*, could not easily be altered so as to use the continuous flow system to the best advantage.

Each scheme has its advantages and its drawbacks, so that it is not merely a question of volume or area or amount of masonry. Inlets and outlets must be considered. Constant flow basins usually receive and

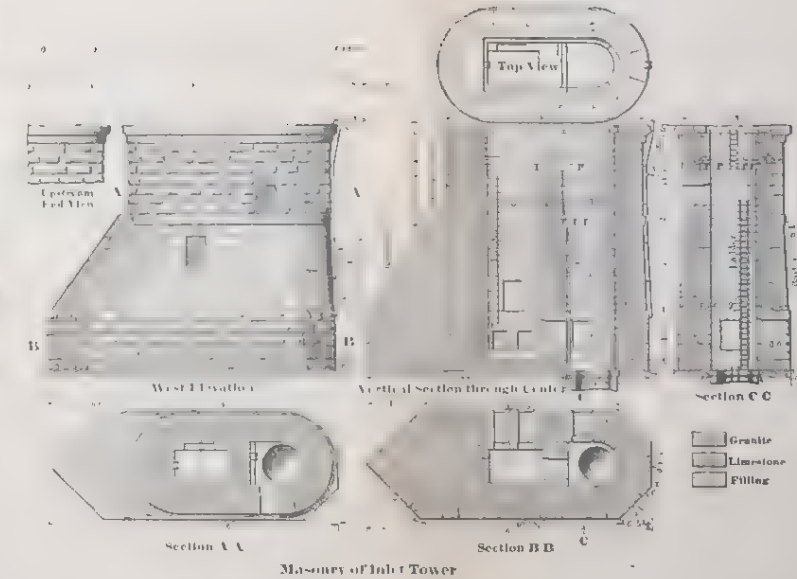
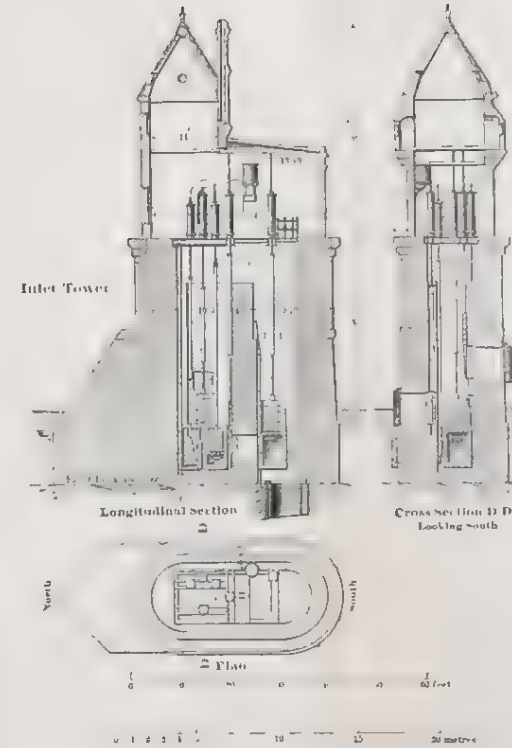
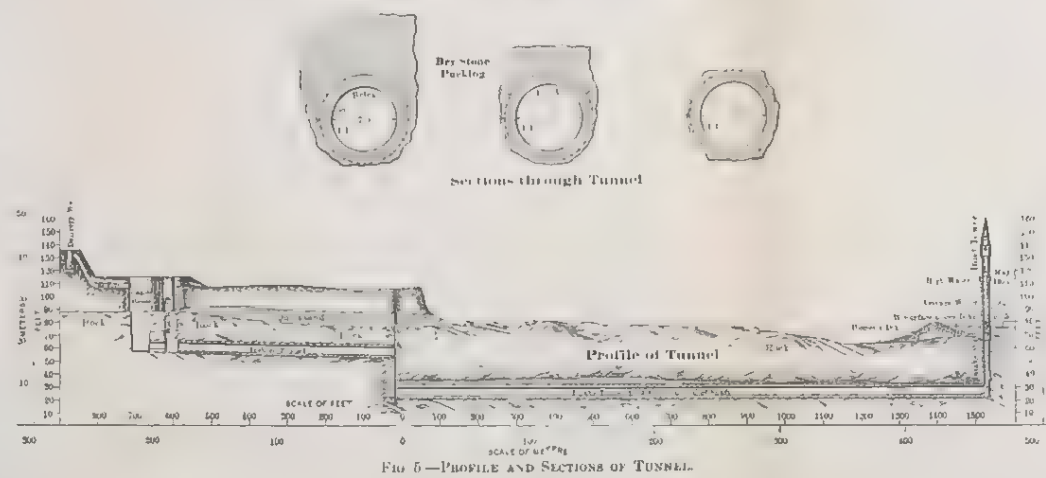
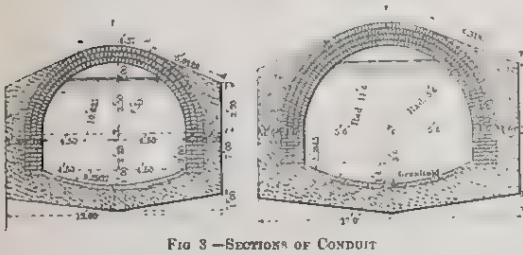
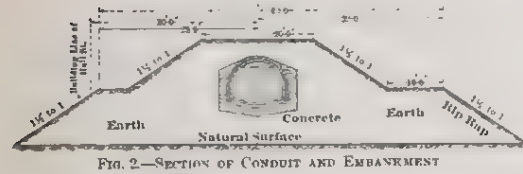
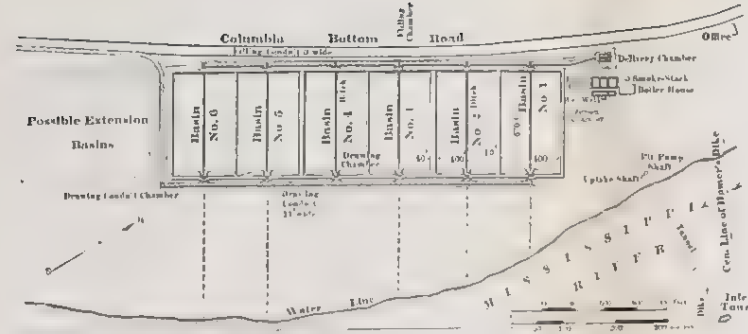
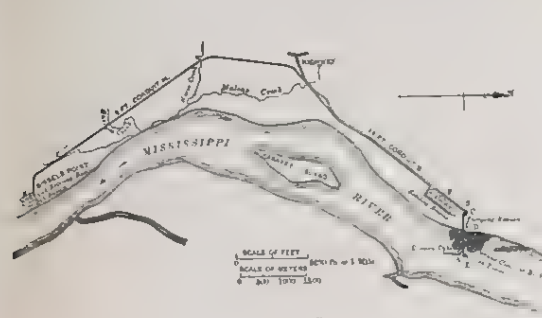


Cross Section D D
Looking South

South

50 60 feet

15 20 metres



deliver their waters over long shallow weirs. They may be built with paved sloping banks. Basins which are drawn off at short intervals must have vertical walls, as the mud would settle on the slopes and in the drawing would be exposed or would slide down. In the matter of banks, therefore, the constant flow basin would be cheaper. The best form for a continuous flow basin is hard to determine. Some think that the water should flow over many weirs; but others dispute this. The filling and drawing plan offers the greater elasticity in operation, as the basins may be gradually drawn down in case of need without seriously interfering with their operation. We thus take advantage of their storage capacity, to prevent a shortage of water in case of accident to our pumping machinery.

The old basins at Bissell's Point were designed for filling and drawing and have given good results. As the water in the river, however, is never twice alike, it would be hard to get scientific expressions of the clearing obtained.

After thoroughly sifting the testimony, the evidence seemed to be stronger on the side of the quiet settlement plan. The following are some of the arguments which would seem in

THEORY

to support this conclusion.

It is very difficult to add water to a vessel containing still water without disturbing the latter.

Any one can learn this by trial. Take a glass of still water containing light sediment at the bottom, and try to add water to the glass without disturbing the sediment at the bottom. On the other hand it is easy to draw water out of a vessel without disturbance. One can readily decant or siphon water out of a glass and yet leave the sediment at the bottom. Now the kinetic energy introduced in filling a basin must be absorbed in friction, and the internal friction of liquids decreases with the velocities of the currents, so that it takes a long time to use up *all* of the energy in this way.

In flowing water the particles never move in parallel straight lines. In the case of water flowing through a cylindrical pipe it is probable that each particle of water is always moving in a curved path, that is, each group of particles always has some angular velocity. The paths of the particles may be likened to the fibres in a rope which have something of the form of a compound helix. Each fibre is twisted around the other fibres of the strand while the strand is twisted around the other strands. It is only by some such system of compound curves that the observed phenomena of flowing water can be explained. Water flowing into or through a reservoir must break up into currents or masses, each mass having both linear and angular velocity.

It is by means of these angular velocities that flowing streams are enabled to sustain solid matter. The swifter the stream, the greater the angular velocities in a vertical plane, and hence the greater is the carrying power.

Let us imagine a cylinder with horizontal axis filled with jelly or similar material. In the jelly is a leaden weight. While the cylinder is at rest the weight sinks with a uniform velocity m . Now revolve the cylinder with a uniform angular velocity a . The weight will tend to describe a circle not concentric with the cylinder. If we eliminate the effect of inertia, the body will move in a closed path and will never sink below a certain level as long as the angular velocity remains unchanged. Hence, with a given depth of water and a given angular velocity, sedimentary particles of a certain limiting size will subside, while those a degree finer will be held in suspension.*

Applying these theories to the clearing of water, we see that the aim must be to reduce to a minimum the angular velocities in the water. If we could suddenly bring a body of muddy water to a state of absolute rest the water would become clear in a remarkably short space of time.

In a constant flow basin the slower the movement of the water the faster it will clear. With a given volume of basin the best result should be obtained by stopping all flow for a time, as is done in the system of filling and drawing. As soon as the inflow of water ceases the internal velocities begin to decrease, rapidly at first but at a diminishing rate. The finer and lighter the sediment, the longer it will take to reduce the velocity of internal currents to the clearing point. A slight decrease in the size of the grain makes a great increase in the time required for settlement.

After having decided on using the fill-and-draw system we took up the question of

THE NUMBER AND SIZE OF THE BASINS.

Taking twenty-four hours as the time of settlement, we used the following expression to denote the working capacity of a set of n basins holding q gallons each :

$$(n - 1\frac{1}{2}) q.$$

That is, we consider that while a basin is being filled, no settling will take place, and that the settling during drawing is equivalent to one-half that of a full basin for the same period. Observations made in our old basins show that the water continued to improve as the basin is being drawn off.

* For discussion of this principle see paper by J. A. Seddon, in JOURNAL OF ASSOCIATION OF ENGINEERING SOCIETIES, Vol. VIII, 1889.

In the new plant, just completed, Fig. 4, we have six basins of 22,000,000 drawing capacity each. By the formula, this gives, for the system, a working capacity of 99,000,000 gallons every twenty-four hours, with twenty-four hours' settlement.

Six to eight basins would seem to be the economical number for our conditions.

It is believed that with a given *volume*, the depth of the basin does not affect the time of clearing.

The economical depth would be that which, with a given expenditure, would hold the greatest volume. It was feared, however, that water less than twelve feet deep might spoil in hot weather, and hence the actual depth was made greater than the computed economical depth.

While not so direct in plan, it was thought wiser to bring the water to the basins on the west side, which is away from the river, as this location puts the *filling conduit* on higher ground, so that it can be built of masonry. The water is drawn from the basins at the side towards the river, as the basins are some six feet deeper at this side. The drawing gates are placed at the very deepest part of the basin, just over the mud-gate which opens into the sewer.

It was thought unnecessary to provide drawing-gates at different levels, as was done in the old Bissell's Point plant; for the water has been shown to be of practically equal clearness at all depths after a few hours' settling.

Connections between the basins and the drawing and filling conduits were made with 60-inch cast iron-pipe, laid in five-foot lengths, with lead socket joints. Allowance was thus made for unequal settlement in the basin walls and conduits, as the lead joints will allow some movement without leakage.

The six basins are as nearly identical in form as they could be built. Each basin has independent connecting pipes and gates, and each basin has an independent flushing sewer to the river.

FOR FURTHER INFORMATION

regarding the general features and details of the plant in question, the reader is referred to the illustrated and descriptive articles in the following journals. In these he will find much that must be understood in the discussion of the points I have outlined, but which, in order to save space, I have omitted to repeat:

The *Engineering Record* for 1892 containst he following series of articles on the St. Louis Water Works Extension:

I. General description of conditions, maps, general elevations and details of inlet tower and gate house, and description of coffer-dam.
April 9, 1892.

II. Hydraulic cylinders in gate-house, details of gates, frames and racks. April 16, 1892.

III. Inlet tunnel and shafts. May 7, 1892.

IV. Wet well, screen chamber, engine-house foundation and delivery well. May 21, 1892.

V. Settling basins, and filling and drawing chambers for same. August 6, 1892.

VI. Sections of 11-foot and 9-foot conduits. August 13, 1892.

VII. Maline Creek Aqueduct Bridge. September 3, 1892.

VIII. Culverts under conduit. September 17, 1892.

IX. Terminal chamber of conduit and connections. October 22, 1892.

X. Construction of masonry conduit. November 12, 1892.

The *Engineering News* has published the following articles :

Settling basins and details. April 18, 1891.

Inlet tower and tunnel. July 4, 1891.

Brick chimney. July 26, 1894.

III. New Machinery.

BY JOHN A. LAIRD, MEMBER OF ENGINEERS' CLUB OF ST. LOUIS.

[Read April 4, 1894.]

IN this paper on the New Machinery for the St Louis Water Works, the writer will give a short description of the different engines under contract, with some details of specifications, lettings, prices, steam connections and proposed system of operating and maintaining. He also hopes to be able at some future time to give the Club some information respecting the duty trials of the different types of engines.

The Water Department has now under contract seven pumping engines of four different types. Their aggregate cost with the boilers will be in the neighborhood of \$800,000. High-service engine No. 6 is a single cylinder, low pressure condensing beam engine of about 16 million gallons daily capacity. It is being built by the Southwark Foundry and Machine Co., of Philadelphia, at a cost of \$110,500.

The first pair of engines for the Chain of Rocks low-service station are compound condensing duplex of 20 million capacity each. They are being built by H. R. Worthington, and will cost, in round numbers, \$300,000.

The second pair of engines for Chain of Rocks are compound condensing engines of 30 million capacity each. They are being built by the Edw. P. Allis Company, at a cost of \$156,000. Finally, the two

Baden high-service engines are three cylinder, triple expansion condensing engines of 10 million gallons daily capacity each. They are also being built by the Allis Company. They will cost \$132,000, and undoubtedly will represent the very latest and best steam practice.

The contracts were all let to the lowest bidders, according to the usual method of letting city work.

High-service engine No. 6 is of the old beam and fly-wheel type which has served the department so well for the past twenty-four years. There were three bidders at the letting :

Fulton Iron Works	\$128,000
Holly Manufacturing Co.	119,000
and Southwark F. & M. Co.	110,500

The contract was awarded to the Southwark Company, and the machine is now being erected in place at Bissell's Point. The indications are that she will be ready for steam about the middle of June. There is very little of special interest in this engine. The main shaft is of nickel-steel, and is the first piece of that remarkable alloy, of any size, which has come to St. Louis. It was made by the Bethlehem Iron Company, and was forged entirely by hydraulic pressure, with a 7-inch hole through the center, and tempered in oil. Test specimens cut out of each end of the finished forging showed a tensile strength of 92,000 pounds, and an elongation 22 per cent. in 4 diameters.

The first bids for engines to be placed at the Chain of Rocks were opened in July, 1890. The specifications did not call for two engines of 20 million gallons daily capacity, but for two engines capable of delivering 600 million gallons in 720 consecutive hours. It is quite unnecessary to say anything on the relative merits of the designs proposed at the letting, as the subject was very well aired at the time. There were three bids presented, as follows :

Builders' Iron Foundry.	\$342,000
Holly Manufacturing Co.	314,000
Henry R. Worthington	299,500

The contract was awarded to the Worthington Company, and the engines are now erected in place at the Chain of Rocks. They are compound duplex condensing engines, with the Worthington high-duty attachment. Each engine has two high pressure and two low pressure steam cylinders, which are respectively 21 and 42 inches in diameter, and four single acting plungers 36 inches in diameter, and under each steam cylinder, all of 80 inches stroke. The engines are balanced by means of walking beams, at the ends of which are placed the oscillating cylinders of the high-duty attachment. The beams are built up of

two diamond-shaped steel plates 1 inch thick, separated 14 inches by cast-iron distance pieces. This, although very weak laterally, is strong and light as a beam. As all of the work is done while the plungers are going down, the beam will always be transmitting the work being done in one cylinder, and this effort will be a pull, tending to raise the beam in the bearings. These machines are 70 feet high, and they stand in the middle pit, which is 50 feet square. There is no masonry foundation, the bed plates resting on the pit bottom, and no connection to the walls except by gangways. The pit is not floored over, and all galleries, stairways and landings are of open work as on marine engines. This allows light to penetrate to the bottom of the pit, and the engineer, standing on the upper gallery, can see clear to the bottom. There is no need of artificial light in the daytime anywhere about the pumps, except inside of them. The joint between bedplates and pit bottom is from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch thick. It was made by grouting with Portland cement. The foundation bolts were also grouted in, and, after the cement was set, we were not able to produce any perceptible movement by hauling down hard on the sixteen 2 $\frac{1}{2}$ -inch foundation bolts.

There is a surface condenser in the delivery pipe, and an independent jet condenser for emergency. The other parts of the engine do not differ materially from those of the well-known Worthington type. In building the Chain of Rocks engine-house the Water Commissioner departed from the time-honored custom of allowing the contractor to use any means which might be at his disposal for erecting the engines, and installed a 15-ton electric traveling crane, capable of sweeping the entire engine-house and having a vertical hoist of 80 feet on the blocks. This crane would also furnish material for a paper, and I will say that it is almost a thing of beauty, and that it has been a joy up to date. It is the first complete power crane which has been placed in a pumping station, and I know of only one crane which has a greater hoist of block. On the day upon which it was turned over to the Worthington Company, they lowered 150,000 pounds of bed-plate 60 feet into position in the pit. Almost any one can design a crane that will *hoist* a given load, but it takes extraordinary capacity to design one which will *lower* the load with perfect satisfaction. This crane has not caused a moment's delay since it was turned over to the contractor, although it has been looked after and operated by an ordinary helper, who had to be taught how to run it.

In the old stations all of the boilers deliver their steam into one great main, to which all of the engines are connected. At the Chain of Rocks there will be three batteries of boilers and three pairs of engines, with a separate steam main connecting each battery of boilers to a pair of engines. In addition to the main connection we have by-

passes by means of which steam can be taken from any boiler for any engine in case of emergency.

The C. W. Hunt system of tracks, charging cars and ash cars, which is in use at Bissell's Point, will be used at Chain of Rocks. Track scales are provided for weighing coal and ashes, and all of the feed water will be metered. This gives an opportunity to compare the duties of different types of engines running in the same house and on the same work; in fact, to make the running of the engines and boilers a perpetual duty trial. The duty required by the specifications is 85,000,000 foot-pounds of work per 1,000 pounds of commercially dry steam, correction being made for entrainment above 3 per cent. Both capacity and duty trials are for 720 consecutive hours.

The two engines under contract by the Allis Company, for the North Pit at Chain of Rocks, are each to pump 900 million gallons in 720 consecutive hours, and are the largest in the department. The letting took place in November last, and there were five bidders, as follows:

Holly Manufacturing Co.	\$287,000
H. R. Worthington	220,000
Southwark F. & M. Co.	203,000
Rankin & Fritsch	193,000
Edw. P. Allis Co.	156,000

The contract was awarded to the Allis Company, and work has been begun on them in their shops. The machines are vertical cross compound, with surface condensers and fly-wheels. The steam cylinders are 28 and 54 inches in diameter. Each engine has two single acting plungers 48 inches in diameter; all 108 inches stroke. If the well-known Reynold's triple expansion pumping engines were to be relieved of one cylinder, one fly-wheel and one pump, the result would be the Chain of Rocks type. These machines, like the Worthington's, will rest on the bottom of the pit and will have no masonry foundations. The duty required is 100 million on a thirty days' test.

The bonus, amounting to about \$375 per million, offered by the city in the specifications for the first pair of engines, as a reward for superior efficiency, cut no figure whatever in the bidding. In writing the specifications for the first pair of Baden engines it was proposed to improve upon this. The duty required was 125 foot-pounds per 1,000 pounds of dry steam on a twenty-four hour test. The bonus offered was in the ratio of \$1,000 for each million foot-pounds of above 125. Almost any builder of modern pumping machinery will claim a duty of at least 140 millions upon his particular type of machine, and the idea was to give these men a chance to put up their hard-earned dollars for the purpose of corroborating their oft-repeated statements. The result of the letting

was a surprise to every one connected with it. There were six bidders for the two engines, as follows:

Groschon High Duty Pumping Engine Co. .	\$223,000
Southwark Foundry and Machine Co. . .	220,300
Holly Manufacturing Co.	198,000
Rankin & Fritsch	173,000
H. R. Worthington	155,000
The Edw. P. Allis Co.	132,000

As a matter of course, the contract was awarded to the Allis Company, and they have begun work on the machines in their shops.

The specifications called for two triple expansion pumping engines of 10 million gallons daily capacity each, to pump against a pressure of 125 pounds, with 125 pounds steam pressure. They will be located in the high-service station No. 3 at Baden. They are of the well-known Reynold's type of vertical triple expansion engines. The steam cylinders 31, 56 and 80 inches diameter respectively, the plungers are single acting, 25½ inches diameter and all are of 64 inches stroke. Each engine has two reheaters, and all the cylinders are jacketed; the high-pressure cylinders with live steam, and the intermediate and low-pressure cylinders with steam at reduced pressure. They are provided with surface condensers, and the air and boiler feed pumps are connected to the low-pressure plunger head. All of the plungers are so loaded that the steam will have to do the same work in lifting the plungers and its connections on the up stroke as in going down and forcing the water. The Reynold's Corliss valve motion is used and Corliss valves are set in the cylinder heads. This brings the clearance spaces down to a minimum. On the high-pressure and intermediate cylinders the percentage of clearance is less than 1½, and on the low pressure less than half of 1 per cent. This is as low as it would seem possible to make it and helps to account for the splendid duty shown by this type of engine. The one feature which distinguishes these machines from all other pumping engines of this size, is the pressure relief valves, which are designed so that a gate in the discharge pipe can suddenly be closed while an engine is running at full speed, in which event all of the water would be by-passed back into the suction pipe. As these pumps will deliver into what is practically a closed system, some such device would seem to be necessary. In starting up, the load may be taken off the relief valves and the engine started slowly, churning the water through the by-pass. Gradually increasing the load on the relief valves, the long column of water may be started very slowly. When the load is increased to the point when no water comes through the by-pass, the pump will have its full load, and any sudden increase in pressure will only cause the relief valves to open proportionately.

On the other hand, the engines are provided with regulators to prevent racing, and if a break in the main should take off all the load, the regulator would stop the engine. If these appliances satisfactorily fill the requirements of the specifications, the machine will be admirably adapted to the very hard service for which they are designed. The plant will be arranged substantially as the one at the Chain, and it is proposed to use a 20-ton electric traveling crane.

It would be very interesting to analyze the various designs which have been submitted at the different lettings and come to some definite conclusion as to the real reason for the great difference in the prices asked by responsible builders on the same specifications. Taking even the three lettings, the machines are nearly all the same weight, and it is difficult to see why the prices vary from \$342,000 to \$132,000; and, in one letting, from \$287,000 to \$156,000. It was evident on the face of the bids at the Baden letting, that the Allis Company was the only one that had sufficient confidence in its machine to pay any attention to the bonus clause. So far as the other builders were concerned, that clause might have been struck out. Worthington's design was the lightest and the cheapest, and, but for the bonus, would have taken the contract. But 125 millions is a high duty for that type of engine, and the bidders could not feel safe in cutting their price when there was a possibility of paying a forfeit at the rate of \$2,500 per million, that the duty fell below 125.

Rankin & Fritsch made a good, fair bid upon a design by Mr. F. W. Dean, of Boston, figured very carefully down to the lowest living price. The design did not differ materially from the Allis engine, and the engine would have been of nearly the same weight. But these bidders were handicapped in two ways. The design would have cost them at least \$10,000, and never having built an engine of this class, they would not have been justified in making a guarantee of more than the 125 million duty required. Taking \$10,000 from the bid for the design, leaves \$163,000 for two machines, or \$81,500 each. There were several reasons for the high bid of the Southwark Foundry and Machine Company. In the first place they spared no pains in getting up the design, but made it the very best they knew how. Their machine was also much heavier than any of the others. Its total weight was about 2,300,000 pounds, while the Allis, and Rankin & Fritsch engines weighed only about 2,000,000 pounds each. Southwark's price per pound was 9.5 cents, and Allis' 6.6 cents, but, adding the \$30,000 which they expect from the bonus, we get 8.1 cents; while the \$50,000 bonus which they may succeed in getting, makes their bid 9.1 cents, which is not so far from Southwark's price. The Allis Company figured on doing 140 million duty, and cut their bid accordingly. This duty

would bring them \$30,000 on both machines, and this, added to their bid, brings it to \$162,000, or \$81,000 for each engine, which is remarkably close to what Ranken & Fritsch figured for building the Dean machine. These figures look very low in comparison with the price paid for the Worthington engines. They weigh 1,675,000 pounds, and the contract price is \$299,500, making the price per pound $18\frac{1}{2}$ cents. Of course these are only very rough comparisons, but they show plainly that the city paid an enormous price for the first two machines. Part of the difference between this and the cost of the later engines is due to reduction in the cost of material. It almost seems that in the short time intervening between the first and the last letting, pumping machinery of this class has passed from a stage when it is built to that of being manufactured.

It is very interesting to note the change which has taken place in pumping engine design in a little over three years. At the letting in 1890 all designs were for beam engines. In 1893 Worthington was the only pumping engine builder in the country who cared to bid on a beam engine. As imitation is counted the sincerest flattery, Edwin Reynolds must feel very highly complimented, for all but one of the great pump builders in this country are paying tribute to the genius of the man who designed and built the first triple expansion pumping engine in America, by substantially copying his design of marine engine applied to pumping engine practice.

The North Point engine at Milwaukee designed under the general supervision of Mr. Reynolds, with a duty of 154 million foot-pounds per 1000 pounds of dry steam, and an indicated horse-power per hour on 11.6 pounds of dry steam, holds the world record for economy in steam using.

When the Chain of Rocks and Baden stations are completed, the works will be able to furnish 100 million gallons daily with only about two-thirds of each plant in operation. Then it is proposed to put the machines on regular watches like the men, only the engines will work two-thirds of the time, and the men one-third; while the engines are resting they will be given a thorough overhauling, as marine engines are given while they are in port. This will add to their life, and it is hoped that it will show an increase in the economy of the machines. When an engine has stood a run of say two weeks, she will be shut down, and one of the crews which has been running, will open up the pump, take off the cylinder-heads, examine all packing, bearings and valves, make all adjustments, and in short give the machine an overhauling similar to what the builders give just before running a duty trial. While this is going on in the engine room, another crew will open up the boilers, give them a thorough cleaning, renew grates and other parts requiring renewal,

examine all valves, fittings and distribution pipe, and put the boilers in exactly the condition which the boilermaker would put them in when preparing for a duty test. By this means the entire plant will be kept constantly tuned up to concert pitch. Whenever an engine is started up after being overhauled, steam cards will be taken from all of the cylinders to see that everything about the valve motion is in adjustment.

By means of a complete set of log books, the duty performed by every engine or battery of boilers on any watch may be laid before the chief engineer. This gives a check, not only on the duty that the engines are doing, but on the work of the men, and the fireman who does his work conscientiously and gets a high rate of evaporation, will be paid more than the one who just manages to make steam enough to keep the engines going. It will also be known, by the duty the machines give, how well the crew does its work in overhauling and tuning them up. With a system something like this it will be possible to elevate the grade of work in all departments, and to educate the firemen to be something more than mere coal-heavers. Why should the city spend one and a quarter million dollars for new machinery of the latest high-duty type and not have the very highest grade of work procurable in the fire-room as well as in the engine-room? The maximum efficiency will not be reached in a month, or perhaps in a year, but by giving the men substantial proof that they are paid to use their heads as well as their hands, we shall, in a comparatively short time, have in charge of the new machinery a corps of men as much more efficient than the old crews as the new engines are better than the old ones.

This leads naturally to the question as to how much saving can reasonably be expected from the use of the high-duty engines; as to the duty obtained from the old engines, no careful duty trial has been made, so far as I know. Reducing to duty the quantity of coal burned, the high service engines give a little over 30,000,000 foot-pounds per 100 pounds of coal. Assuming five pounds evaporation, which is a little low, we get 65,000,000 on a 10-pound basis. Or, reduced to steam per horse-power per hour, we get something near thirty pounds.

As to what may be expected of the new engines, I will consider only the high service, as the ratio of duties between the new and the old low service engines will be as high as corresponding ratios on the high service.

It would not be safe to take results of twenty-four-hour duty trials as a basis of computation, and the only figures I have at hand for comparison, which are worth considering, were given me by Mr. Benzenberg, City Engineer of Milwaukee. He says that the North Point engine, which is very similar to our Baden machine, designed by the

same man and built by the same company, gives a monthly duty of 120,000,000 foot-pounds per 100 pounds of coal, without any deductions. The coal used is anthracite, and gives about $8\frac{3}{4}$ pounds evaporation. This brings the monthly duty up to 136,000,000 on a 10-pound basis. Can we reasonably expect as high results on the Baden engines? It would seem so. The water pressure is higher, the steam pressure a little higher, and the clearance spaces on all the cylinders a little less. Surely it would not be out of the way to expect 130,000,000 on a 10-pound basis. Granting this, the coal bill will be reduced one-half, as also the cost of coal-passing and firing, and one engineer will run two engines. But the item of wages will cut very little figure, for a certain number of men must be employed in connection with a plant of this size. Let us suppose we do the same work and save half of the coal. One of the old 15,000,000 engines takes fifteen tons of coal to a watch of eight hours. They will run two-thirds of the time, or two watches a day, through the year.

Then, on a 15,000,000 gallon engine, we would save fifteen tons per day, or 5,475 tons per year. At the present contract price for coal, this amounts to \$7,150—quite a respectable sum—which, capitalized at 5 per cent., gives \$143,000, which would more than build a high-duty engine of equal capacity.

I have gone very hastily over the subject of the new machinery for the water-works. As most of the work remains to be done and none of the engines have been started, I have only been able to tell what we proposed to do and give the results we hoped to obtain. There will be material for several papers of very high scientific as well as practical value on the duty trials of the several machines. The water commissioner intends having all tests conducted by experts of acknowledged ability and experience in this class of work. Mr. C. C. Worthington, in speaking to the writer about the proposed tests, said that he would consider the reports of the same, if made under the general supervision of Mr. Holman, a most valuable addition to pumping-engine literature.

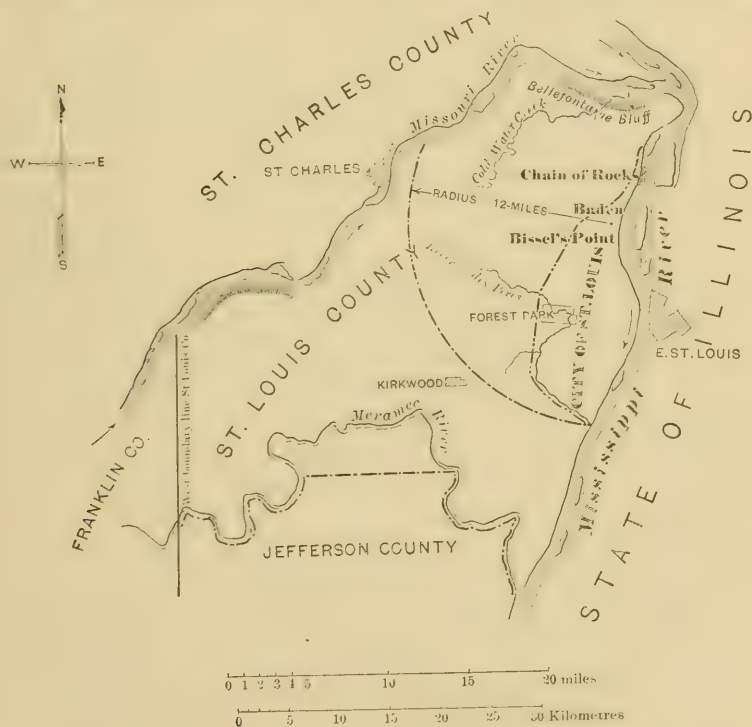
IV. Quality of the Supply.

BY ROBERT E. McMATH, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read April 18, 1894.]

A FEW years since, a question as to the quality of Mississippi, and especially Missouri, river water would have been treated with derision, but now even the old time St. Louisian must admit that the foundation of his faith is badly shaken. A vast area is tributary to the Mississippi at the point where our supply is to be taken, and each small district

pays that tribute in a manner characteristic of itself. The result is a composite of waters from many sources. Mingled with the water is the debris of mountain and plain, as matter in suspension or in solution. Of the matters in suspension, whether of vegetable, animal or mineral origin, none adds any desirable quality or character to the water. By common consent it is desirable to be rid of them all. Of matters in solution, some may be neutral, beneficial or harmful for one or more of the uses to which water is put in a great city. A water pure according to scientific standards would suit no one. If chemists, individually connected with the varied interests of water users, were called upon for formulas of the ideal



SKELETON MAP OF ST. LOUIS COUNTY, MO. SCALE, 1 INCH = 12 MILES.

water, a strange diversity would be developed. Nature's mixture, as we have it, probably comes as near the mean of such ideals as is possible, for it contains a little of everything from everywhere. Recently some of our people have awakened to the probability that our water has an undue contribution of something from Chicago, and hence in large part the query which furnishes occasion for this paper.

As to the source of our supply I remark, first, that this must of necessity be the river. Second, that the location at the Chain of Rocks

is plainly designated by nature, for that is the only possible point of supply on the Mississippi, and it is also on the only practicable line by which a supply can be brought from the Missouri.

The first of these propositions needs no argument, except to put aside the occasionally suggested scheme of using Meramec water, by reminding you that the Meramec drains a mineral region and is liable at low stages to be mineralized to an extent unfitting it for use as drinking water. Concerning the scheme to bring in the water of St. James Spring, I will say no more than to suggest that water which has probably traversed a series of bat guano caves is not necessarily pure, even though it be clear.

To establish the second proposition, I call attention to the fact that the Bellefontaine Bluff on the Missouri is the only place, until we approach the limits of St. Louis County, where the river runs along a permanent bank. That bluff can be reached from the Chain of Rocks by a tunnel four and a half miles in length that will deliver Missouri water into the wet well at the Low Service Station.

Since the river has disposed of a site above St. Charles, once considered possible, by leaving that site more than a mile inland, there are but two places where a permanent intake could be maintained, that at Bellefontaine and one near or beyond the west line of St. Louis County, distant by an air line twenty-one miles from the nearest point in the west boundary of the city, at Shrewsbury Park. The same point being, by air line sixteen miles from Bellefontaine Bluff. The conclusion is that the location at the Chain not only serves the wants of the city of to-day, but absolutely commands the water supply of that greater St. Louis which some people can see with the mind's eye.

Much criticism has been expended on those who overruled for a time the recommendations of Mr. Kirkwood that the Chain of Rocks be the location of the Low Service and Baden that of the High Service stations, and who established both at Bissell's Point; but the fact that we find among those whose counsels prevailed, such men as Gerard B. Allen and James B. Eads warns us against too hasty judgment. A glance at the city map will suffice to prove that Bissell's Point is well located as a point of distribution. It is not now a proper location for an intake, and, as a result, the city has on its hands a low-service house and three well-worn engines, and a boiler-house with a battery of antiquated boilers for which it will shortly have no further use; but the settling basins, as filter beds or as a storage reserve, retain their full value, as do also the high-service houses and engines, less wear and tear. The Kirkwood plan was good, as is evidenced by the fact that we are now carrying it out, so far as location is concerned; but it outran the resources and actual needs of the day when it was proposed. The map

shows us the Cold Water or St. Ferdinand Creek emptying into the Missouri near the upper end of Bellefontaine Bluff. This creek drains an area which, even now, is being invaded by the suburban site speculator, and which at no remote date will receive the sewage of a large population. But if we indulge the visions of our prophetic eyes, we are liable to fall into the error of the housewife who, by preparing for an extra good dinner, left breakfast uncooked. We therefore adopt the Chain of Rocks for the location of pumping and settling works, and point to the Bellefontaine Bluff as a possible future intake point.

What shall we say as to the location of the high-service stations?

Let it be understood that we are dealing with the question of a water supply for St. Louis from 1894 to 1920 at farthest.

If arcs of different radii be struck from the Baden location as a center, it will appear that a greater area can be supplied from that point than from any other which can be reached by gravity flow from the settling basins. The location is on a direct line from the settling basins to the northwest corner of Forest Park. Hence it is an eligible location for the supply of the western part of the city and of the adjoining suburban territory.

The highest ground in the city limits north of the Pacific Railroad is almost centrally divided by the line mentioned. The line to the high elevations south of the Pacific Railroad is also direct and as short as any. The highest elevation within the city limits north of the railroad is about 180, above directrix, at the southwest corner of Forest Park; the highest south of the railroad is 205, at the Female Hospital. The highest graded point in the old city limits (prior to 1876) north of the railroad is 140; south of the railroad, 159.

Taking 30 pounds pressure at street grade as standard, a reasonably satisfactory supply from the present works north of the railroad is limited by the grade contour of 130, while south of the railroad the limit is that of 125 to 120. These facts suggest that the Baden Station should be designed to supply the high levels, and that the Bissell's Point Station be maintained to supply the lower levels.

Should it be deemed necessary to filter the water for domestic use, a third standard of pressure may well be considered. For very many manufacturing establishments filtered water will be no better than settled water. Most of these establishments are now, and for transportation reasons they always will be, located on ground below the grade contour of 75. If, therefore, a plant be operated to deliver settled, but unfiltered, water in this low district, manufacturing interests will be promoted by a less water rate than would be possible if filtered water alone were supplied, and the further problem of finding employment for ground now depreciating in value will be solved. Still farther, if users of large

quantities of water locate on the low lands north of Bissell's Point, it will be entirely practicable to supply them at a still lower rate with settled water direct from the conduit.

To carry out this idea, one of the high-service houses at Bissell's Point would handle water, filtered probably in the present settling basins, and pump 30 million gallons per day against a head of about 220 feet; the other pumping daily 30 million gallons of unfiltered water against a head of about 130 feet. The Baden Station might be divided into two services, the one part pumping against 220 feet head, the other against about 315 feet. Of course, economy demands that, so far as possible, territory which requires the high head should be served separately.

Consideration has been given to the suggestion of a supplementary detached station for the highest service; but the weight of argument seems to be in favor of concentrating all pumping machinery at the main stations.

From this outline of a possible development of the water works, a matter having a close relation to the consideration of quality, I pass to the still more closely related question of purity; meaning, by purity, freedom of the water from any mixture or contamination which would render it dangerous to human health.

From what I have already said you will have gathered that, as we are at present situated, the water supply must be taken from the Mississippi River at the Chain of Rocks, or, as an alternative, from the Missouri River at the Bellefontaine Bluff.

When the Chain of Rocks was adopted as the location whence the supply for the immediate future should be taken, it was virtually assumed that water there taken would be wholly from the Missouri. The well-known phenomenon that an apparent line of demarkation between the waters of the two rivers is noticeable at the city front was triumphantly quoted as demonstration that none but Missouri water could reach the proposed intake. Hence it was urged that to go to the Missouri itself was an unnecessary expense. While coming down the river in October, 1887, I saw what led me to the conclusion that at that time, and probably at all low stages, a mixture of the waters of the two rivers took place immediately at their junction.

What I saw was the water of the Missouri dropping into that of the Mississippi over a fan-shaped reef extending across the mouth of the Missouri; the muddy water of the Missouri, plunging under the clearer water of the Mississippi, came to the surface in irregular boils and patches, some rising near the Illinois shore. Later, I noticed that although the water appeared densely muddy when looked at vertically from the steamer's deck, yet the bow-wave, when first started from the

stem and broken, showed comparatively clear. I was thus compelled to recognize the fact that Mississippi water tended to overlies that of the Missouri, and hence that it might, and probably did, extend well over to the Missouri shore, and that consequently some proportion of Mississippi water would be taken into a supply drawn at the Chain of Rocks.

Reporting what I had seen to Mayor Francis and my associates on the Board of Public Improvements, and thus raising a question as to the sufficiency of the traditional belief, I also suggested the advisability of making an investigation, chemical and biological, of the water of the Illinois River, in order to determine, if possible, whether any risk to the health of St. Louis would be incurred by taking our water supply at a point where it is well nigh certain that water which has passed through the sewage pumps at Bridgeport will in some proportion enter that supply.

Being at the time a believer in the doctrine that dilution and opportunity for oxidation would certainly render sewage harmless, my expectation was that such an examination would bring out strong evidence that the supply might be taken there without risk of harm. Later evidence has shaken my faith in the doctrine, but has not proven the contrary.

As a consequence of my report, the Water Commissioner, taking due precautions to guard against misleading results, obtained samples of water from the Mississippi above the influence of the Missouri, from a corresponding point in the Missouri, and at the Chain of Rocks, and obtained a chemical analysis of them by Prof. W. B. Potter, Manager of the St. Louis Sampling and Testing Works. The details are fully set forth in the report of the Water Commissioner for the fiscal year ending April, 1888, pages 71, 72 of the Report of the Board of Public Improvements.

These results confirm the observations I have described, and prove that, although the characteristics of Missouri water greatly predominate at the Chain of Rocks, the influence of the Mississippi water is clearly manifest. The increase of the mixture of the waters with the distance traversed is shown by the results at Bissell's Point. It must therefore be taken as an established fact that at low stages, or during the fall and winter months, the water which has been furnished our city from Bissell's Point has contained a considerable proportion of Mississippi River water, and probably some of it from the Illinois and the Bridgeport pumps; also that the supply taken at the Chain of Rocks will contain a diminished proportion of water from the same sources.

Since the foregoing evidence was obtained, the city of St. Louis has been visited by a serious outbreak of typhoid fever, lasting through the fall and winter months of 1892 and into 1893. Our Board of Health,

by its official action, laid the outbreak to the charge of a contaminated water supply, and so gave publicity and official sanction to a report injurious to our city.

The progress of this outbreak, as per official report, was :

	Deaths.	Cases.
January, 1892,	13	22
February, "	8	22
March, "	7	18
April, "	9	14
May, "	8	13
June, "	6	32
July, "	15	35
August, "	8	70
September, "	23	142
October, "	45	261
November, "	111	1923
December, "	189	945
January, 1893,	36	114
February, "	17	35
March, "	8	40
April, "	8	
May, "	3	
June, "	2	
July, "	11	
August, "	42	
September, "	32	
October, "	20	
November, "	25	
December, "	11	
January, 1894,	2	
February, "	7	
March, "	8	

The summer of 1892 was a flood season in the Mississippi, and the bottom lands north of Grand Avenue were submerged for many days. The sewer outlets along the entire city front were blocked by backwater for months. Yet it is reported that the 1st, 2d, 3d, 4th, 5th, 6th, 8th, and 13th wards, where these influences were most potent, furnished comparatively few cases. The disease was chiefly prevalent between Twelfth Street and Vandeventer Avenue, Victor Street on the south and Herbert Street on the north; or, by house numbers, between 1200 and 3900 east and west, 2500 south and 3500 north.

It is not apparent why a charge was brought against the water supply, which had certainly the same character throughout the city when some of the most densely populated wards were nearly exempt. It will also be observed that the disease was present to a sufficient extent to have put the health authorities on their mettle during the early

months. The decided spread began in June, reached its maximum in cases in November, and quickly fell. The cause can hardly be found in the water supplied, for the increase began when the river was approaching a flood stage, when certainly the probability of contamination by sewage from other cities must have been infinitesimal. As the river approached a low stage, and the probabilities of sewage contamination increased, the disease abated; and when the rigors of a severe winter covered the streams with ice, and so brought the sewage of Chicago and other up-river cities to our doors under conditions as unfavorable to self-purification as can well be imagined, the disease fell to its normal I think that the water supply is entitled to a verdict of acquittal, having shown an alibi. A further cry was made, and the city was nigh being dragooned into a large expenditure to hasten the transfer of the intake to the Chain—by temporary expedients that would have seriously interfered with the permanent works. But that the flow from Harlem and other suburban creeks had nothing to do with the typhoid scare is well evidenced by the fact that very few cases of the fever occurred within their drainage areas.

I conclude that as yet no evidence has appeared to justify an unfavorable opinion as to the quality of our water supply. Further, the analyses of 1887, already referred to, indicate that, contrary to traditional ideas, the Mississippi water is not only clearer than that of the Missouri, but has materially less sulphuric acid, lime, magnesia, chlorine, iron and alumina, and is lower in hardness. Therefore, so far as chemistry is concerned, it is the preferable water.

The quality of our water, so far as appearance and usefulness are concerned, is open to improvement. The mud, and sometimes the coloring matter, are unbearable. In days not very remote, the St. Louisian who did not argue that the mud was a positive advantage, was the exceptional character. The one who does so argue is now the exception. Still, I think that all of us, when in other cities, particularly in those which take their supplies from the great lakes, find something lacking, and we long for a satisfying draught of Mississippi water. I am not disposed to attempt telling you affirmatively what the lack is; but negatively I will say it is not the absence of mud. Experience and experiment has taught our water-works men that settlement for twenty-four hours in a reasonably quiet basin will clear the water of nearly all of its sediment. A cloudiness will remain after a long period of rest. Apparently, the interest of purity rather favors the adoption of a twenty-four-hour period for settlement. It is also to be noted that at the breaking up of winter there is usually a time when a persistent dark color, a disagreeable black deposit and an unpleasant flavor prevail; and these are not removed by settlement. In summer flood time the mud is at its maximum; but the

water, when settled, is free from unpleasant flavor, although it retains a stain.

What may we expect when the new works are in operation? So far as freedom from mud is concerned, I know of no reason to look for better results than were realized when the Bissell Point works were first completed, results which continued until the capacity of the settling basins became overtaxed.

Our spring and summer supply never gave us clear water, and probably never will. I anticipate that the advancing tastes and habits of our people will demand something better than can be attained by settling alone. Whether that something will require filtration, or may be practically attained by some process of clarification, is an unsolved question of great importance. The success of many filters depends largely upon the use of some coagulant, of which alum may be named as a representative, because most frequently used. If just the right proportion of alum is used, no trace of it can be found in the effluent, and, of course, no harm can follow. If a coagulant is to be used to assist filtering, is it not better to use it at the low-service works, and for all the water pumped, than at filter stations near the high-service pumps, further inland, for perhaps a part?

That a substantial gain, as to quality, would follow a more complete clarification, is indicated by the average results of a series of analyses of samples taken from mid-channel, from the distributing well and from the clear well.

The average results from 16 groups taken at stages of water ranging from 67.6 to 100.2 (directrix = 100), and in season from mid-winter to mid-summer, show:

	Channel.	Parts in 1,000,000. Dist. Well.	Clear Well.
Alb. Ammonia	1.046	1.033	0.411
Free Ammonia	0.038	0.046	0.019
Nitrites	0.0002	0.0003	0.00018
Nitrates	0.383	0.381	0.442
Oxygen consumed	31.60	33.00	15.90

Or, assembling series of similar dates, in order to show the gain by sedimentation:

Date of Collecting.	Gauge of River.	Temp. of Water.	Oxygen Consumed. Parts per 1,000,000 by Weight.		
			Channel.	Dist. Well.	Clear Well.
June 27, 1893	89.9	27° C.	41.40	47.80	17.80
July 8, 1893	89.5	27° C.	46.80	44.60	15.40
July 12, 1893	85.0	27° C.	45.80	48.60	20.80
July 19, 1893	84.0	28° C.	43.40	44.00	18.20
July 26, 1893	79.6	28° C.	38.40	38.40	15.20
August 31, 1893	72.0	22° C.	21.40	25.80	17.10
November 5, 1893	70.4	10° C.	7.80	5.80	5.20
December 6, 1893	67.6	1° C.	7.00	7.00	5.60

If the sedimentation, occurring during the passage of the waters through our present settling basins, reduced the carbonaceous matter by an average of 60 per cent. when the river was 20 feet or more above low water, then, with the better settling facilities, afforded by the new works, we may confidently expect a much higher percentage of purification.

A comparison of determinations of albuminoid ammonia would sustain this conclusion, but purification in this respect will not necessarily be accompanied by a corresponding improvement in appearance.

If to natural settling we add the clarification due to use of a coagulant, we may well expect a water as free from objectionable matter, organic and inorganic, as is practicable; still, not a water to satisfy the fastidious, for at times it will have a dark shade, and at all others more or less of a whitish cloudiness.

To meet the last requirement, filtering must be resorted to. But, it may be asked, should the city be compelled to filter the entire supply in order to meet a demand arising from only a part of its people? Probably less than half the water supplied would be improved for the use to which it is put by this last and costly process. Considering the fact that filtered water rapidly deteriorates, would it not be better to leave the filtering to those who want it?

These are questions any one may ask, but who has the answer ready?

As yet, I have not touched upon the question that perhaps, in your minds, is most vital to the quality of our water, viz.: How will it be affected by the completion of the Chicago drainage scheme?

Let us assume the worst conceivable condition: the Missouri and Mississippi dead low; their joint volume about 45,000 cubic feet per second, and the Illinois frozen from its mouth up, so that whatever may under present conditions enter the Chicago canal, will be delivered at the mouth of the Illinois as if it had come through a closed pipe. Then, as was the case in 1892-3, nearly 2 per cent. of the water passing St. Louis will have passed through the Bridgeport pumps. When the drainage canal is in operation, with a flow of 10,000 cubic feet per second, the proportion of water that has been subject to Chicago influence will be 18 per cent., a prospect which, of itself, is not reassuring. Let us look closer.

Estimating the sewage proper as equal to the water supply, we may roughly estimate that of the delivery of the Bridgeport pumps 20 per cent. is sewage and that the remaining 80 per cent., while originally lake water, has been in very bad company during its leisurely trip through the Chicago River. Under the proposed condition of 10,000 cubic feet flow per second, the sewage proportion will fall to about 4 per cent., and the 96 per cent. will have passed through Chicago without stopping.

Using these proportions, it seems that $\frac{3}{10}$ of one per cent. of the present low stage Mississippi flow has been in the condition of sewage, and that this proportion will rise to $\frac{7}{10}$ of one per cent., when the $2\frac{1}{2}$ million mark of Chicago population within the sanitary district shall have been reached. Hence, unless we are helped by mere dilution from the beginning, the quality of Mississippi water will, as a whole, have suffered from the Chicago scheme.

But these and similar arguments prove nothing in reality, although the figures represent facts.

The underlying question is: Does water, which washes nearly everything else, wash itself? In other words, does it, by any process, rid itself of filth after contamination? We know that it does: by sedimentation and by chemical change, in which lower forms of organic life may have an important part.

But how are we to know, when the chemist assures us that all the ammonia that left Chicago has passed into harmless nitrates before reaching St. Louis, that some colony of pathogenic bacilli has not made the voyage with unimpaired vitality? I have no answer to this question. When we think of all the risks and dangers we are said to incur with every breath we inhale, every morsel we eat and every draught we drink, we may well wonder that our harp of a thousand strings keeps in tune so long. While ignorant of these risks, the race lived and it probably will continue to live in spite of what biologists tell us.

Scientists are to be commended for their patient and painstaking researches, for seeking to penetrate the mysteries which surround us; and if, under strong temptation, they sometimes tell us things before they know them themselves, as possibly some have done in the matter of St. Louis water, we engineers need not throw stones at them, for we have glass sections in our own house.

Much has been said locally about the scheme by which Chicago aims to cast her filth before us. It may be wrong for her to do so, but St. Louis cannot of herself collect the proof; partly because she cannot find the men and the means for the demonstration, and partly because any action in this direction will be attributed to jealousy, and any proof furnished will be much discredited on account of traditional rivalry.

The questions involved are of the utmost importance, not only to the cities immediately interested, but to all the cities and states on the earth. It is, therefore, proper that the United States Government be asked to make a full investigation of the facts presented by the Illinois River, and of the effect of Chicago sewage on it, especially when the river is frozen.

A disinterested examination would lead to wise legislation, regulating, controlling or prohibiting the discharge of sewage into streams and

rivers, small and great, by Minneapolis, St. Paul, Omaha, Kansas City, St. Louis and smaller cities.

As the population of this country becomes more dense, the question of the quality of water supply will become more important, and our efforts may of necessity turn from the prevention to the cure of pollution.

To completely guard the purity of our streams is not possible, and hence the purification of water will probably become a necessity; but that probability should not lead to indifference as to the pollution of the streams.

Returning for a final glance at the Chicago plans, I will say that already a very large part of Chicago's territorial area, and a considerable part of her present population, are outside of the sanitary district to be served by the canal. Moreover, the canal is only an outlet for Chicago drainage, and it must be remembered that drainage is a matter entirely distinct from the disposal or treatment of sewage. Chicago's sewer system will have to be radically remodeled to complement the drainage plans. Perforce she will have to separate sewage from storm water, and will have to pump a large part of the sewage. Under this necessity, imposed by natural conditions, it will be comparatively easy for the State of Illinois, or, in default of her action, for the general government to impose a further condition that the sewage be purified before delivery into the waters of a navigable stream.

When I promised the Secretary of the Club to undertake one of a series of papers on the new water works, I did not appreciate the poverty of the information available to me concerning quality of supply. Certainly, there is much that might, and should, be known concerning Mississippi or Missouri water, the variations of quality with season and stage, and other matters of inquiry.

No systematic study of our water had been made prior to 1893, and then only by chemical analysis. In preparing this paper, I have had in my hands the report of Chemist John T. Wixford to Water Commissioner M. L. Holman, with liberty to use it; but, with the exception of a few figures showing grouped results and a general statement of conclusions, I have made no use of the information it contains, chiefly because I am persuaded of the truth of the statement somewhat fully presented in the report by Mr. Wixford, that the usual lines of inquiry in examinations of water supply are of little or no value when applied to Mississippi water. Such studies usually take note of color, odor, taste, turbidity, solids in suspension (and their composition). They involve the determination of dissolved gases, and special determination of chlorine, organic carbon and nitrogen, ammonia salts, nitrites and nitrates, and also take account of hardness.

The color of unfiltered Mississippi water varies from muddy-brown to whitish, according to the character of the suspended matter. Filtered, the color is a faint yellowish-green. The odor is inappreciable, and the taste is agreeable, except for a short period at the breaking up of winter, at which time the color is dark and persistent. The origin of this color and taste is not known; but it is not probable that a remedy or preventive lies within human power. The turbidity is always considerably greater at high stages than at low, and when the river is rising than when it is falling. The causes are uncontrollable. The solids in suspension are, both in quantity and in variation, far beyond the possibility of discovering the influence of sewage contamination, and their determination would have no value.

The dissolved gases are constituents of the atmosphere, and are harmless. They thus indicate no recent sewage contamination. It is needful, first, to know the normal quantities, as it is only the excess that is to be taken into account. This, for varying conditions and temperatures, is not practicable.

The chlorine test is valueless, because we do not, and cannot, know the normal scale. The Massachusetts State Board of Health has published a map showing the iso-chlors for that State, which vary from 0.65 part of chlorine per 100,000 near the coast to less than 0.10 part in the western part of the State. If an iso-chloric map of the Mississippi and Missouri basins were made, the maximum would probably surround the Kansas salt fields; but as we never could tell what proportion of the flow at any time came from a particular part of the drainage area, we could make no use of the map.

Organic matter, animal or vegetable, is mainly composed of carbon, hydrogen, nitrogen and oxygen in varying proportions. Animal matter decomposes more rapidly than vegetable matter, and contains more nitrogen. By decomposition, these elements are converted into carbonic acid, water and nitrates. The changes are the result of the activity of micro-organisms, and do not take place in their absence.

Albuminoid ammonia represents the nitrogen in organic matter which has not begun to decompose. In itself, it does not indicate whether it comes from animal or vegetable matter. By one determination, July 12, 1893, there was present 1.799 part in 1,000,000.

Analyses by the Massachusetts Board of Health give 5.302 parts in 1,000,000 as the average yield of Lawrence sewage. Hence, Mississippi water at mid-summer stage may have one-third as much albuminoid ammonia as average sewage. It is not necessary to follow out Mr. Wixford's computation to show that it would take the sewage of 454 cities like St. Louis to account for this proportion of albuminoid ammonia.

Hence, to look for trace or proof of sewage contamination by analysis, is as hopeless as the search for a needle in a haystack.

Not to follow the technical report further, it is suggested that a study of our water supply involves the development of a broader field of investigation than has yet been traversed, and one which can scarcely be covered by the limited resources of our water department.

V. The Filtration of City Water Supplies in the Light of Recent Researches.

BY ROBERT MOORE, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read May 2, 1894.]

ONE of the most important and difficult problems with which the modern city is confronted is how to obtain an adequate supply of wholesome drinking water.

The first solution in point of time is, in the great majority of cases, found in surface wells, one of which is sunk for the supply of each house or small group of houses. For a time this source of supply is satisfactory both as to quantity and quality, and it may be that for many years no water works beyond the town pump are demanded by any public or private need. With the lapse of time and the growth of population, however, the water obtained from surface wells is found to deteriorate in quality. The cesspools after a time pollute the wells and under favoring conditions convert them into breeders of disease. The favorite home of typhoid fever, the world over, is the country village. But as a rule other considerations of less intrinsic importance have a greater influence in producing a desire for something better. The private citizen wants to have water brought into his dwelling, and an ample supply of water under pressure becomes necessary as a protection against fire.

The next step, therefore, is to bring the water of the nearest lake or river into the town, and the private well is supplanted by the public water pipe. This step is attended not only with an enormous gain in security from fire and in comfort of living, but also, in nearly all cases, with a marked improvement in the public health. Statistics compiled by the Massachusetts State Board of Health* show that in the twenty years from 1865 to 1885, during which all the larger towns had introduced public water supplies, the deaths from typhoid fever had fallen from a rate of 13.94 to 3.09 per 10,000, a decrease of 70 per cent.

This reduction of the death-rate, however, is not universal, and

* Twenty-second Annual Report, p. xxii.

even in the same city is not always constant. In a few cities having a public water supply we find the typhoid death-rate to be increasing rather than decreasing. Three well-marked instances of this kind are cited by the Massachusetts State Board of Health,* to wit: Holyoke, Lowell and Lawrence; and a notable instance of the same kind is found in our neighboring city, Chicago. In each of these cities careful investigation has shown the water supply to be unmistakably polluted by causes which can be positively identified. In the case of Chicago the rise in the typhoid fever rate has been shown by Dr. F. W. Reilly, Secretary of the Illinois State Board of Health, to follow the freshets whereby the waters of the open sewer known as the Chicago River have been carried into the lake and thence into the city water pipes; whilst periods of long-continued dry weather, during which the Bridgeport pumps are able to reverse the natural flow of the river, are followed by corresponding depressions in the fever curve.

These cases, however, are only illustrations of what is likely to happen hereafter to many other cities. The increasing density of population in the territory draining into our lakes and rivers is certain to cause pollution, and in the cities dependent upon them as sources of water supply, the public water pipes are sure in time to become carriers of disease. How to ward off this new danger is a problem which has for a long time troubled many cities in the old world and which is beginning now to trouble not a few cities in the new world.

The first and most natural suggestion by way of remedy is to change the source of supply, substituting a new one that shall be free from danger. This was done by Glasgow, which, prior to 1859, took its water from the Clyde, but which since then has taken it from Loch Katrine, thirty-four miles distant in the Highlands. As a result, the city has shown itself, in every epidemic of cholera since then, to be cholera proof, although it had always before been one of the most vulnerable. This is also being now done by the city of Manchester, which is building works to take its water from Thirlmere, more than eighty miles distant in the Lake District.

Such a change of sources evidently affords a complete solution of the problem, and not a few have maintained that it is the only solution. For example, Mr. Chas. Watson Folkard, Associate of the Royal School of Mines of England, in a paper read January, 1882, before the Institution of Civil Engineers, after a discussion of the various methods of water analysis, uses this language: †

“The conclusion that once-contaminated water never purifies itself sufficiently for dietetic purposes becomes inevitable; and, as chemical

* Twenty-second Annual Report, for 1890, p. 525 and following.

† Proceedings, Institution of Civil Engineers, Vol. 68, p. 66.

analysis fails to give reliable evidence as to its fitness or the reverse, the author believes that the only safe test of the wholesomeness of a given water is by tracing it to its source and ascertaining that no objectionable impurities gain access to it. This will at once condemn all rivers flowing through a populous country ; and, if it be considered that a river is the natural drain of a district into which everything soluble or suspensible finds its way, it will not be a matter of wonder that this should be the case. No Conservancy Board can keep pollution out of a river ; it must receive all the rain falling within its watershed (excepting, of course, that which is evaporated) together with the overflowings of cesspools and the sewage of towns within the same area. It is part of the great circulatory system of the earth, which it is vain for man to attempt to control. This being so, it is evident that rivers, except near their source, can only afford polluted water, and a problem utterly insoluble by man is presented, viz., the purification of foul water on a large scale."

In the discussion which followed, in which a number of very able men, including Prof. John Tyndall, took part, the preponderance of opinion was in full agreement with the author. That drinking water for individuals and for communities should be taken only from sources that were not "contaminated nor contaminable" was the judgment of nearly all.

But, unfortunately, for the great majority of towns such sources as these are inaccessible. For most of them there is practically no choice. St. Louis, for example, unless she would do worse, must draw her water-supply from the Mississippi or the Missouri ; Louisville and Cincinnati, from the Ohio ; and Chicago, from Lake Michigan. Each must take what there is at hand and make the best of it. The real problem, then, for many cities now, and for nearly all cities at sometime hereafter, is how to render wholesome a water supply that has been contaminated.

The earliest device for obtaining a pure supply from a river whose water is for any reason objectionable, is to take the water, not from the river directly, but from wells sunk in the sand near by. By this method, which is sometimes called "natural filtration," a water free from sediment or visible impurity, is obtained, and if the quantity required be not large the result may be entirely satisfactory. In the greater number of cases, however, this method is not attended with success. Most often there is a deficiency in quantity, and not infrequently the quality also is at fault. As is well known, the water obtained from wells alongside the Mississippi River near St. Louis is much harder than the river water, and is usually unfit for use in steam boilers. At the water works near Lake Tegel, one of the works for the supply of Berlin, the water was at first taken from wells alongside the lake. But experience showed it to be so rich in iron and so favorable to the development of objectionable vegetable growths

that the water was rendered useless. The wells were therefore abandoned and the water is now taken directly from the lake.

The next device in the order of time was the artificial sand filter, first constructed by Mr. Jas. Simpson, Engineer, for the Chelsea water works of London in 1839. This consists essentially of a shallow reservoir with a collecting drain through the center and with lateral drains of porous tiles or bricks, without mortar, leading into the central drain. On top of this system of drains are laid from three to four feet of gravel and sand increasing in fineness to the top. Through this sand bed the water is allowed to percolate slowly into the collecting drains, whence it is led off to the pumps for distribution.

This simple device was from the first so effective in removing sediment and improving the appearance of the water that in 1852 its use was by law made obligatory upon all the London water companies except for water from deep or artesian wells, and it has ever since been in continuous and successful operation. The example of London was soon followed by other cities, both in England and on the Continent, so that when Mr. Kirkwood visited Europe in 1866 on behalf of the Board of Water Commissioners of the City of St. Louis, he found filtration plants in operation in Berlin, Altona, Nantes, and Marseilles, as well as in Leicester, York, Liverpool, Edinburgh and Dublin.

So long as the pollution of water was regarded as due solely to particles of dead organic or inorganic matter in suspension, this method of purification left nothing to be desired. By its use, turbid waters were rendered clear and, so far as the eye could judge, pure. But when, in the progress of scientific investigation, it became evident that the harm of polluted water lay, not in dead matter at all, but in living organisms invisible to the naked eye, and that the clearest and most sparkling water was sometimes the most deadly, a strong revulsion of opinion took place, and the benefits of filtration came to be generally regarded as delusive. This sentiment is well voiced in the paper of Mr. Folkard and the discussion thereon, already referred to.

"Filtration," says he, "is another remedy put forward as infallible by those who have not grasped the subject. How can filtration affect substances dissolved in water? And, as far as the minute organisms found in putrescent bodies are concerned, they could pass a hundred or a thousand abreast through the interstitial spaces of ordinary sand as used for this purpose."*

And Mr. Homersham declares that in some respects and at some seasons filtration really injures the water by the collection of a layer of

* Proceedings, Institution of Civil Engineers, Vol. 68, p. 68.

organic matter on top of the sand which furnishes "pabulum for the insects" as he terms them.*

This, added to the difficulty of finding and recognizing the morbid germs—a difficulty so great that, as Dr. Tidy expressed it, "one could no more analyze a water for a germ of typhoid than one could analyze a brain for an idea"—left the matter in a quite hopeless condition which seemed to justify the opinion of Mr. Folkard already quoted, that the purification of foul water on a large scale was "a problem utterly insoluble by man" and that there was no defense against impure water except boiling or distillation. This, however, is a defense which is almost impossible of application on a large scale and, as those who have tried it in their own households know, very difficult of application even on a small scale.

Now, as it happened, in the very year in which this paper was read, 1882, Dr. Robert Koch of Berlin gave to the public† his then newly discovered gelatine-plate process, which made it possible to fix, cultivate and even count the micro-organisms in any sample of water. This at once put the biological analysis of water, which Dr. Tidy had just declared to be an impossibility, upon the footing of an exact science, and students were not wanting to apply the new method to the investigation of the phenomena of the filtration of water through sand.

Among the earliest in this new field of inquiry was Percy Faraday Frankland, Professor of Chemistry in University College, Dundee, and son of Dr. Edward Frankland, official water analyst for the Registrar General and for the Local Government Board of England. Prof. Frankland began at once to study, by the aid of the gelatine-plate process, the various methods of water purification, and in particular to ascertain, by a series of observations running through several years, the results actually attained by the filters of the London water companies. The facts thus found are set forth in a paper read by him before the Institution of Civil Engineers in April, 1886, and in two papers submitted to the Royal Commission on Metropolitan Water Supply and published with other documents accompanying their report of September 8, 1893. In brief, his findings are these:

(1) That the chemical changes effected in the water by the filters of the London companies, summarized in the following table, are so small as to be quite insignificant.

* Proceedings, Institution of Civil Engineers, Vol. 68, p. 70.

† Mittheilungen, Kaiserliches Gesundheitsamt, 1882.

TABLE SHOWING THE CHEMICAL RESULTS OF THE FILTRATION OF THAMES WATER BY THE LONDON WATER COMPANIES, EXPRESSED IN PARTS PER 100,000.

	Before Filtration.	After Filtration.
Total solid matter	28.40	26.20
Organic carbon . . . . .	.123	.119
Organic nitrogen . . . . .	.025	.022
Ammonia	0	0
Nitrogen as nitrates and nitrites . . . . .	.077	.089
Total combined nitrogen . . . . .	.102	.111
Chlorine	1.6	1.6
Hardness { Temporary	11.5	10.9
{ Permanent	7.1	7.1
{ Total	18.6	18.0

(2) That the filters have a most remarkable efficiency in removing micro-organisms from the water. The record of three years' working of the filters is given in the following table, which shows that on an average, out of every 100 micro-organisms in the untreated river water, the numbers stated in the table were removed by the water companies before distribution.

Water from the	1886	1887	1888
	Organisms.	Organisms.	Organisms.
Thames	97.6	96.7	98.4
Lea—East London Co.	96.5	95.3	95.3

From a later series of observations made in 1892, Prof. Frankland finds the average number of bacteria per cubic centimeter in the filtered waters to be only 29, or a trifle more than $\frac{1}{3}$ of one per cent. of the average number in the Thames water—20,000. And, as the numbers in the filtered water seem to bear no relation to those in the unfiltered water from day to day, he considers it certain that of those found in the filtered water nearly all are attributable to post-filtration sources. In other words, the efficiency of the filters in the removal of bacteria is practically 100 per cent.

(3) That this extraordinary biological efficiency of the filters depends upon the formation of a superficial gelatinous deposit or membrane upon the top of the sand, which membrane acts as an almost impervious obstacle to the passage of micro-organisms, and that it is of the greatest importance that this membranous film should not be ruptured by the application of excessive or irregular pressures in the filtration.

It thus appears that Mr. Folkard's army of microbes marching "a hundred or a thousand abreast through the interstitial spaces" has somehow been put to rout, and that the cause of their discomfiture is found in the superficial layer of organic matter which, according to Mr. Homersham, should furnish them with pabulum—all of which illustrates anew the extreme danger of *a priori* reasoning in matters of physical science.

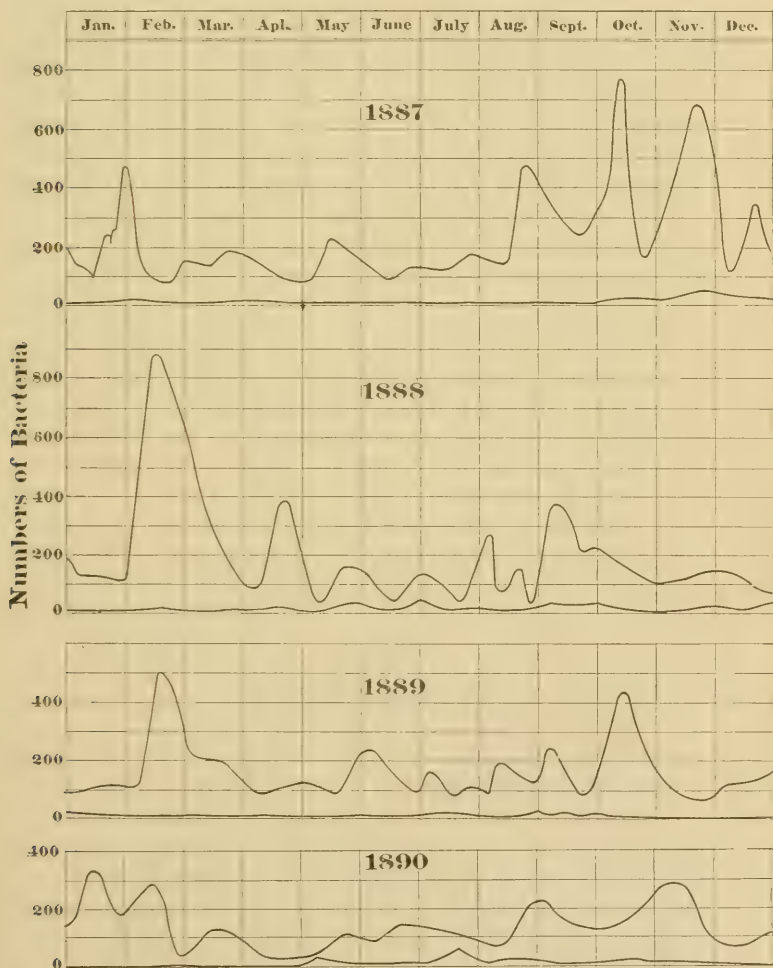


FIG. 1. NUMBERS OF BACTERIA IN FILTERED AND IN UNFILTERED WATER AT ZURICH, SWITZERLAND, 1887—1890.

In each of the four diagrams the upper and lower curves show respectively the conditions obtaining before and after filtration.

Other observations of the same character, running in each case through a series of years and all pointing to precisely the same conclusions, have been made by the Massachusetts State Board of Health at Lawrence upon a number of experimental filters, and by the authorities of Berlin and Zurich upon the filters used for the city water supply.

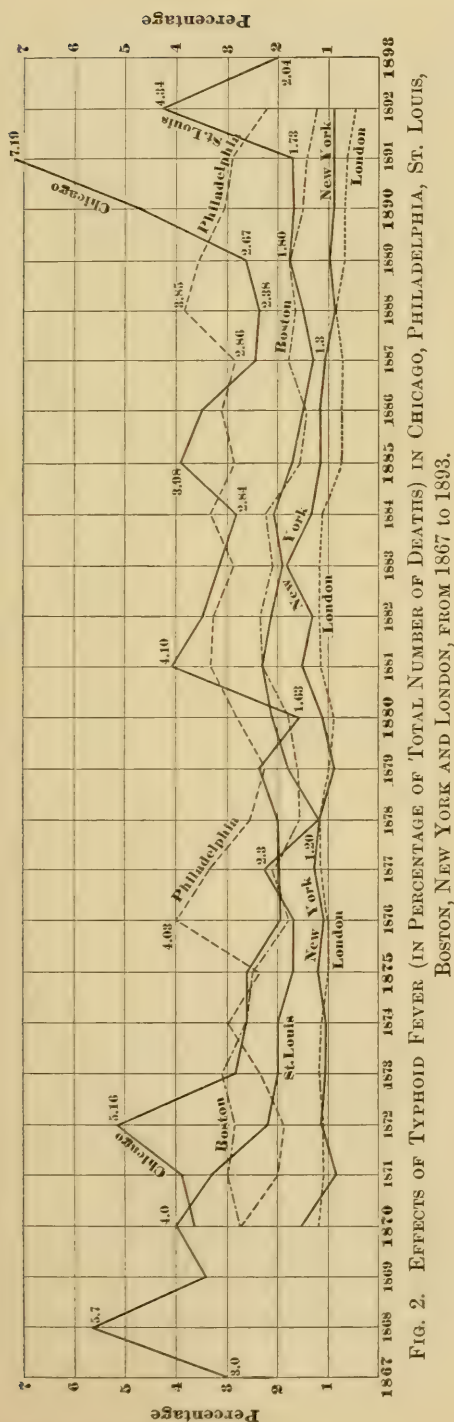
The Lawrence experiments show that when filtering at a rate of from two to three million gallons per acre per day, which gives a velocity of 6 to 9 feet in twenty-four hours, 99½ per cent. of the bacteria in the applied water can be removed by filtration. At slower rates practically all can be removed. At Zurich, where the ordinary velocity of filtration is 25 feet in twenty-four hours, or more than double the London rate, the average number of bacteria per cubic centimeter in the water after filtration is 20. As, however, the number in the water before filtration is unusually low—about 200—the percentage of removal is only 90, or much less than in either of the other cases.

Fig. 1, showing the results of the working of these filters during four years from 1887 to 1890 inclusive, is interesting as showing the tendency of the number of micro-organisms in the filtered water to remain constant without regard to the fluctuations in the number in the water before filtration, a fact already noted in the London and in the Lawrence experiments, and strongly suggestive of the conclusion that the bacteria in the effluent are due to the drains of the filter itself and not to the applied water.

But the benefits of filtration are seen more clearly in the mortuary records than in the records of the laboratory. At Zurich, for example, the typhoid mortality in 1880, before the construction of the present filters, was 4 per 1,000 of the population. Since then it has dropped to 0.4 per 1,000, a decrease of 90 per cent. The effects of filtration in London are shown in Fig. 2, taken from a paper read before the American Statistical Association in January, 1892, by Prof. Sedgwick and Mr. Allen Hazen, which shows the typhoid mortality in London since 1870 as compared with that of several American cities. It is reproduced here with the addition of the typhoid curve for St. Louis since 1867. From this it will be seen that notwithstanding the fact that London draws its water supply from two small rivers draining a territory densely populated, it has had for more than twenty years a typhoid rate continuously lower than that of any large American city.

Even more significant is the report of Dr. William Farr, Registrar General, upon the experience of London with cholera in 1866*, in which he points out that the field of greatest fatality was almost coincident in its boundaries with a section of East

* See Report of Registrar General, July 25, 1868, pp. xv and following.



London, which, for a time just then, was supplied with unfiltered water—a fact to which he attributes the deaths of nearly 4,000 persons. Of like purport is the now familiar story of Hamburg,* which upon the advent of cholera in 1892, and in spite of the warning given a few years before, by an epidemic of typhoid, was found still drinking the unfiltered water of the Elbe. As a result, nearly 8,000 persons lost their lives from cholera in eight weeks, whereas the adjoining city of Altona, which drank from the same stream after it had received the sewage of Hamburg, but not until the water had been filtered, was, except for certain imported cases, almost wholly exempt from it.

Indeed, no fact in sanitary science is now more firmly established than that properly conducted sand filtration is an almost perfect defense against the dangers of polluted water.

Of the immense and ever growing importance of this fact to all cities dependent upon rivers for their water supply, not a word need be said. But certainly the name of James Simpson, the Engineer who, building “better than he knew,” constructed, more than fifty years ago, the first filtration plant, and whose

* Proceedings, Institution of Civil Engineers, Vol. 88, p. 507 and Vol. 114, p. 425.

work has already saved so many thousands of lives, should be held in grateful remembrance as that of one of the benefactors of mankind.

The bearing of all this upon our own city is self-evident; but a few words, by way of reminder of some of the special features of our own case, will perhaps be pardoned. As is well known, in the plans for new water works for St. Louis, made in 1865 by Mr. James P. Kirkwood, was included a recommendation of filtration. In 1866 Mr. Kirkwood went to Europe on behalf of the Board of Water Commissioners, to make a detailed study of the subject; and, in his report, a copy of which is in the library of the Club, is found a plan for filtration works at St. Louis. Almost the sole object in view at that time was the clarification of the water by the removal of the sediment which was then, as it is now, a cause of reproach to us by the outside world and a source of serious offense even to the citizens native born. With the lapse of time, during

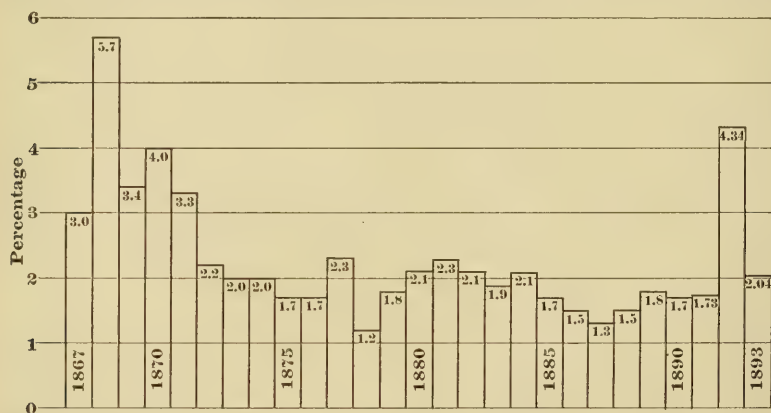


FIG. 3. EFFECT OF TYPHOID FEVER (IN PERCENTAGE OF TOTAL NUMBER OF DEATHS) IN ST. LOUIS, FROM 1867 TO 1893.

which we have made so much progress in other directions, this reason for filtration has certainly not lost anything of its force.

But a more cogent reason is found in the diagram of relative mortality given in Fig. 2, on which the typhoid rate for St. Louis from 1870 to 1892 inclusive ($2\frac{1}{2}$ per cent. of the total mortality) is seen to be more than double that of London ($\frac{9}{10}$ of one per cent.) for the same period. To make more evident the special characteristics of the St. Louis curve it is shown separately in Fig. 3. On this you will note especially the very high rate from 1867 to 1871, the drop in 1872 and the continuously lower rate from that year on until 1891, the sharp rise in 1892 to $4\frac{34}{100}$ per cent., and the equally marked decline to 2 per cent. in 1893. Worthy of consideration also are the coincident facts that 1872 was the first year

after the removal of the water works intake from the foot of Bates Street, where the water was mingled with the sewage of Rocky Branch and Gingrass Creek, to Bissell's Point, where the water was then comparatively pure, and that in 1893 the pumps, whereby the sewage of Harlem Creek is now discharged into the river below the water works, were first put into operation—facts which in both cases suggest a possible, not to say probable, relation of cause and effect.

But be this as it may, it is certain that our water supply is at times subject to serious infection, which, as time passes, is sure to be largely increased, and equally certain that by means of proper filtration works, coupled with the closing of all wells, our typhoid rate can be reduced to or below that of London. With our present population this means the saving of 1,300 cases and 160 lives each year. And all this can be brought about at a first cost not exceeding two millions of dollars and an annual cost, including interest, of not more than one hundred and fifty thousand dollars—sums which are trifling when compared with the benefits which their expenditure will insure.

TESTS OF NON-CONDUCTING PIPE-COVERINGS.

BY JOHN A. LAIRD, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read October 3, 1894.*]

THIS paper is a report of tests made at the St. Louis Water Works for the purpose of selecting the most suitable covering for pipes, boiler-shells, etc., in the new pumping station at the Chain of Rocks. The specifications for the engine and boiler work called for a covering satisfactory to the Water Commissioner. Not having any data at hand which seemed to be perfectly satisfactory, we concluded to give the different coverings a comparative test under conditions as nearly uniform as possible. For this purpose there were purchased asbestos sponge moulded sectional covering, asbestos fire felt sectional covering and magnesia sectional covering, all for 1-inch pipe. Also, asbestos sponge cement felting, asbestos cement felting, plastic magnesia and fossil meal. Tests were also made on plaster of Paris and sawdust, moulded into covering for 1-inch pipe.

The different coverings were subjected to chemical examination by Mr. Wixford, chemist of the water works, with the following results:

ASBESTOS SPONGE, MOULDED.

Plaster of Paris	95.8
Fibrous asbestos	4.2

ASBESTOS FIRE FELT.

Asbestos	82
Carbonaceous matter not determined	18

MAGNESIA (SECTIONAL).

Magnesia	92.2
Fibrous asbestos	7.8

MAGNESIA (PLASTIC).

Magnesium carbonate	93
Fibrous asbestos	7

ASBESTOS CEMENT FELTING.

(Probably) Powdered limestone	64.5
Plaster of Paris	3.5
Asbestos	32

ASBESTOS SPONGE CEMENT FELTING.

(Probably) Powdered limestone	59
Plaster of Paris	10
Asbestos	31

FOSSIL MEAL.

Insoluble silicate	80
Carbonaceous matter, hair, paper, sawdust, etc.	12
Soluble mineral matter	8

* Manuscript received December 10, 1894.—*Secretary, Ass'n of Eng. Socs.*

The chemical analyses were approximate and were intended only to give some practical idea as to the composition of the different coverings.

The tests were only comparative, and the apparatus consisted of

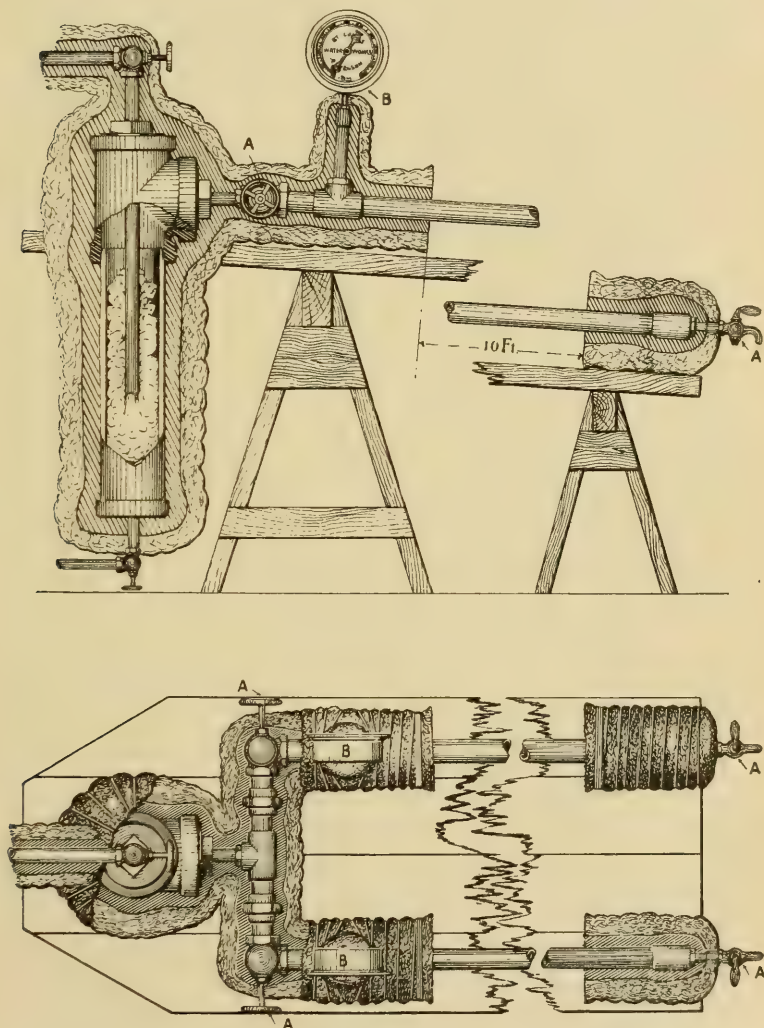


FIG 1. APPARATUS FOR TESTING PIPE-COVERINGS.

two 1-inch pipes about 24 inches apart, connected at one end and set at a slight incline. Fig. 1 gives a general idea of the connections.

The pipe was first put together and tested. All connections, valves and fittings were then covered with 1 inch of plastic magnesia. When

this was dry it was covered with 1 inch of hair felt, bound on with twine. There were left bare on each line 10 feet of 1-inch pipe, to which the coverings to be tested were applied. All the coverings tested were 1 inch thick.

Before beginning a test, steam was allowed to blow through the pipes for some time. Two independent methods of comparing the insulating properties were used. First, by measuring the water condensed in a given time; second, by closing valves at A—A and noting the reduction of pressure on the gauge B at intervals of one minute.

On all condensation tests the gauge pressure was held at 25 pounds. The water was drawn off every fifteen minutes and was measured in cubic centimeters. Each test was continued for four hours. The mean results are tabulated below.

CONDENSATION TESTS.

Name of Covering.	C. C. Condensed Per Hour.
Magnesia (plastic) :	334.
Magnesia (sectional)	335.3
Asbestos fire felt	367.5
Asbestos sponge moulded	371.3
Fossil meal	376.2
Plaster of Paris and sawdust	438.
Asbestos fire felt cement	563.7
Asbestos sponge cement	604.
Bare pipe	1085.

On all pressure tests the gauge pressure was made 25 pounds at the beginning. Four tests were made of each covering, and the mean results are plotted in Fig. 2.

Both methods show that the magnesia plastic and sectional coverings possess the best insulating powers. Compared with the asbestos fire felt and sponge moulded, the difference is $3\frac{1}{2}$ grams per foot of 1-inch pipe per hour. There will be the equivalent of 6,000 feet of 1-inch pipe in engine and boiler houses at Chain of Rocks.

$$6,000 \times 3\frac{1}{2} = 21,000.$$

$$\frac{21,000 \times 24 \times 2\frac{1}{4}}{1,000} = 1,134 \text{ pounds of water per day.}$$

$$\frac{1,134}{6} = 189 \text{ pounds of coal per day.}$$

$$\frac{189 \times 365 \times \$0.547}{80} = \$47.20. \text{ Saved per year by using magnesia}$$

instead of asbestos.

A question which naturally arises, in a comparison like the above, is that as to the durability of the coverings, and I will say that the

magnesia sectional covering, which has been on pipe at Bissell's Point for four years, shows no signs of deterioration; also that the asbestos sponge moulded covering, which has been on pipes at Harlem Creek for less than two years, is becoming soft and the plaster of Paris seems to be reduced back to the original powder, with nothing but the fibrous asbestos to hold it together. Another question is that of steam pressure. The experiments were made at the High Service Station, No. 2, and it was found convenient to have all tests made at 25 pounds gauge pressure. As the working pressure at Chain of Rocks will be at least 125 pounds, the relative efficiency of insulation will be slightly changed, but, in the writer's opinion, not enough to change the conclusions here arrived at. After giving the matter considerable attention and thought, he has no hesitation in recommending the magnesia covering, sectional and plastic, as the best insulation in the market.

THE ST. LOUIS EXTENSION OF THE ST. LOUIS, KEOKUK AND NORTHWESTERN RAILROAD.

Address

By B. L. CROSBY, RETIRING PRESIDENT OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read December 19, 1894.]

THE St. Louis Extension of the St. Louis, Keokuk and Northwestern Railroad leaves the old line of the road at a point, *O*, Fig. 1, in St. Charles County, about two thousand feet south of the crossing of the Cuivre River. From this point it runs, for about thirty miles, in an easterly direction, down the long stretch of bottom-land between the Mississippi and Missouri Rivers, locally known as "Missouri Point." It then turns to the south, and crosses the Missouri River at a point about eight miles above its mouth. From the Missouri River it runs in a southerly direction, through the bluffs and uplands of St. Louis County, striking the city limits of St. Louis at a point about half a mile east of the Bellefontaine Road, and thence down through the Mississippi bottom, and along the river front to a southern terminus at Franklin Avenue, a distance of about forty-eight and one-half miles.

The construction of this extension has been carried through under the direction of Mr. George S. Morison, of Chicago, as Chief Engineer, and the writer, as Resident Engineer, has had charge of the location of the whole line and of all the construction, except the line through Missouri Point. During the time that the foundations of the bridge across the Missouri River were being put in, he was relieved of the charge of the work in St. Louis City and County.

The line was located with maximum grades of 26.4 feet to the miles and a maximum curvature of 3° , so that the full trains hauled over the old line can be brought through to St. Louis without doubling and without increase of motive power, whereas, during the time that the St. Louis, Keokuk and Northwestern Railroad ran into St. Louis over the Wabash Railroad, a full train hauled to St. Peter's made two full trains from St. Peter's to St. Louis, over the Wabash. This location, of course, involved some pretty heavy work in the broken ground of St. Louis County, but the extra cost will be far more than balanced by the reduced cost of operation.

The line down through the bottom-lands on Missouri Point involved very little work of special interest, being of the usual type of flat prairie work, almost entirely on embankment, raised above the level of any high water, of which there is any record. For about twenty-four mile,

from where it leaves the old line, the road was built as single track, but the balance of the line to St. Louis is double track.

Two small streams, Peruque and Dardenne Creeks, are crossed, and the bridges over these creeks have one novel feature, which may be of interest. The bridges are alike, and consist, each, of an 80-foot deck-plate girder, the substructure being of piles driven within cylinders. The cylinders are filled with concrete around and over the piles, and cast-iron caps on the cylinders form the seats for the girders. The novel feature is, that, in order to keep the slopes of the banks away from the cylinders, the girders are continuous over the piers, extending back of them, 10 feet at each end, making a cantilever arm to carry the ends of the stringers extending to the bank. This makes the length of the girders actually 101 feet, over all.

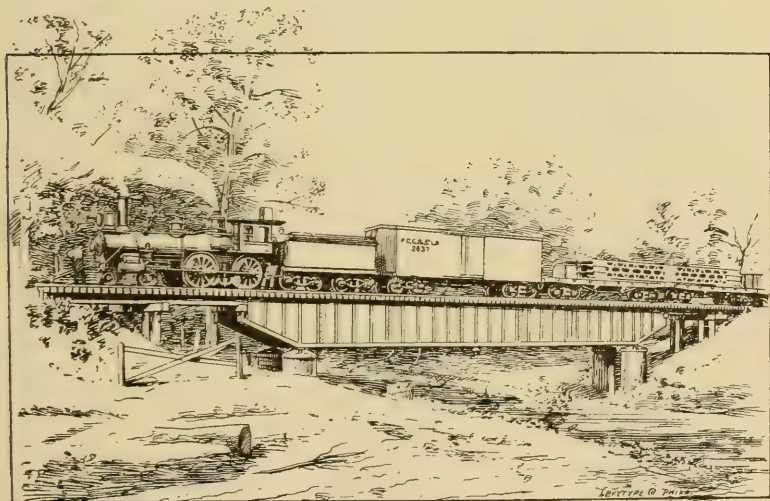


FIG. 2. CANTILEVER PLATE-GIRDER BRIDGE OVER PERUQUE CREEK.

This portion of the line has been ballasted with a light, sandy gravel, but it is intended to ballast this track with burnt clay next spring, and this ballast is now being burned at a point on the line.

The line through St. Louis County has a good deal of heavy work, the heaviest cuts reaching fifty feet in depth.

With two exceptions, all of the county roads are carried over or under the tracks, the overhead bridges generally consisting of timber-bents on each side of track, with roadway stringers of 6 inches x 16 inches, spaced thirty inches centers, and floored with 4-inch hard pine; but at the Bellefontaine Road crossing, on account of the angle at which

the road was crossed, the span was so long that latticed iron girders were used, with 6-inch x 12-inch timbers for floor beams, floored with 4-inch hard pine. Two of the roads are crossed by the tracks overhead, on through plate-girder bridges of 41 feet span. The abutments for these bridges are built of hard-burned brick, laid in Portland cement, with a coping of Romona oolitic limestone, and the foundation is of piles and concrete.

The culverts on the line are, with two exceptions, of cast-iron pipe, 24 inches to 48 inches in diameter.

One of the two exceptions is a 10-foot brick barrel culvert, with foundation and supporting side-walls of concrete. The lower portion of the barrel, where it is supported by the concrete, consists of two rings of brick, and the arch of four rings.

The other, known as the Coldwater Arch, is rather a novel structure. The line of the railroad crosses the valley of Coldwater Creek about fifty feet above the bottom of the creek. The bed of the stream at this point is right on the solid limestone rock, and on the north side was an abrupt bluff of limestone, rising about twenty-five feet above the bed of the creek. It was decided to put in an arch at this point, to carry the creek through, and to build a solid embankment over it. The rock bluff was cut away enough to carry the creek through at right angles to the line of the road, and an arch of twenty feet radius constructed, with one side springing direct from the rock at the bottom of the creek, and the other side from a rough skew-back cut in the rock about 16 feet above the true spring line of the arch, the rock bluff below forming the north side of the culvert. This culvert is 90 feet in length; the arch, built of hard-burned brick, laid in Portland cement, is 36 inches thick; the haunch walls are built of Louisville cement concrete; the head walls at each end are of brick, with Romona stone copings; and the wing walls are of heavy rubble masonry, set in Louisville cement, and having copings of Romona stone.

The line, through both the city and the county, is ballasted throughout with broken stone. On the line in the city of St. Louis there are several interesting pieces of work.

Just south of the city limits the new water works conduit is crossed by means of a bridge consisting of three through plate girder spans, each 73 feet 6 inches over all, supported on two piers and two abutments built of hard-burned brick, laid in Portland cement, on foundations of piles and concrete, with copings of Berea sandstone.

About two miles south of the city limits we reach the north end of the main freight yards, which extend to Grand Avenue, about two miles further south. About five hundred acres of land here are owned by the railroad company, giving it abundant room to increase its yard capacity,

as business may require. At present about twenty miles of track have been laid in this yard, which is so laid out that it can be used as a gravity or poling yard, if so desired. At its north end are located the round-house, coal chute, sand house, oil house and storehouse. The round-house is a brick structure built on a forty-stall circle, but only thirty stalls have been built. The turn-table, 66 feet long, is of steel.

The northern half of the yard is crossed by Harlem Creek, which, after passing under the new water works conduit in Hall Street, originally wandered around in a very irregular course on its way to the river. As so many tracks would have to be carried over this stream, it was considered best to change the channel and to run the creek straight from Hall Street to the river. Borings were accordingly made, which showed that rock for foundation could be found at a depth of from twenty to twenty-four feet below the surface of the ground, and above low water in the river, so that there would be no serious difficulty in excavating to the rock, at the proper season. It was decided to build an arched culvert to carry the creek, and for the present, to build the arch only under the property embraced within the limits of the present yard.

This culvert, or sewer, is I think, the largest in area of any in this country. The bench walls are placed 30 feet apart and are built of Romona limestone, laid in Portland cement and backed up with Louisville cement concrete. The spandrels also are of Louisville concrete. The bench walls, up to the spring line of the arch, vary in height, according to the elevation at which the rock was found, from 6 to 11 feet; the face stones average $2\frac{1}{2}$ feet in depth from the face, with headers every third stone, not less than $3\frac{1}{2}$ feet in depth from the face, and the top course is cut in the form of a skew-back to receive the arch. The back of the wall has a batter of one in eight.

The bench walls were built for the whole distance from the edge of the Mississippi River to the western limits of the company's property, at Hall Street, a distance of 1,560 feet, and they have since been continued by the city of St. Louis to connect with the water works arch over Harlem Creek. The arch is built of hard-burned brick laid in Portland cement. It consists of seven rings, with a total thickness of about 32 inches. This arch is segmental, with radius of 16 feet and a rise of 11.43 feet. As above stated, the arch was turned only within the limits of the yard as now constructed, a distance of 607 feet. The ends were left toothed out, so that at any time the arch may be continued, the bench walls being already built to receive it.

The quantities of material in this culvert, and the cost, are as follows:

Earthwork,	74,144	c. y., at	\$.40	\$29,657 60
Concrete,	6,068.01	" "	4.75	28,823 05
Face stone,	2,145.88	" "	12.00	25,750 56
Brick masonry,	2,515.82	" "	11.50	28,931 93
Difference in cost between Portland cement and Louisville, used in leveling up foundation under face stone of bench walls				453 05
Total				\$113,616 19

In explanation of the apparently high price paid for excavation, I would say that it was very wet work, that a considerable portion had to be handled with derricks, and further, that the price included the refilling over the arch, and distributing the balance of the material where it was needed for filling the yard.

The next important piece of work is the Mound Street Yard. This yard contains about fifteen acres, and is located between Tyler Street on the north, Mullanphy Street on the south, First Street on the east and Second Street on the west. This yard is for the shipment of car-load freight, and has track room for about four hundred cars, each of which is accessible by teams. The driveways between these tracks are all paved, some with granite, but the larger portion with vitrified brick, of which I will later speak more fully. A passenger station, located at the southwest corner of the yard, is at present used for the suburban trains of the Keokuk, and for all trains of the Missouri, Kansas & Texas. The latter railway enters the city over the tracks of the St. Louis, Keokuk & Northwestern. On the west side of the yard is located a five-stall engine house, with turn-table and coal chute. Before work was commenced on this yard, the ground sloped with a grade of about 6 feet per 100 from Second Street to First Street, and from Brooklyn Street to Mullanphy Street nearly all of the ground was covered by buildings. The territory embraced within the limits of the yard was crossed by three streets.

An ordinance was obtained from the city of St. Louis, vacating these streets in consideration of the construction and maintenance by the railroad company of a bridge across the yard from Second Street at the foot of Mound Street, and an inclined drive-way leading from the bridge to First Street at Brooklyn Street. This bridge was constructed in 1891. It consists of a steel span of 293 feet, supported on brick abutments, with Bedford stone coping. The eastern abutment where the turn onto the incline is made, was built hollow, and it serves as a storehouse for material used about the yard. The incline is a timber structure, with a grade of 6 feet in the hundred. Both bridge and incline are paved with pine blocks.

After the construction of the bridge the whole area of the yard was

graded down to the level of First Street, leaving the elevation of the yard about 20 feet below that of Second Street, except at the extreme northern end.

Second Street is supported by a substantial retaining wall, built of Louisville cement concrete, with a facing of a single thickness of hard brick, laid in Portland cement, the brick being laid in Flemish bond, so as to tie the facing back into the concrete. The wall is finished on top with a heavy coping of Bedford limestone, surmounted by a substantial iron gas-pipe railing. This wall was built with a vertical face, and the back is stepped out as required by the depth. It was founded on rock for the whole length. This form of construction, which gives a smooth neat wall, has proved very satisfactory.

In making the excavation, rock was found in the southern and western half of the yard, and over fifty thousand yards were taken out. Nearly all of this was crushed and used for ballasting the yard and main line tracks. About ninety thousand yards of the earth excavated were used for filling a deep quarry which occupied the eastern half of the block between Brooklyn and Mound Streets, and the balance for embankments on the line north of Wright Street.

As above stated, the drive-ways in the yard are largely paved with vitrified brick. This, I believe, is the first pavement of the kind laid in St. Louis, certainly the first of any extent. There are about 16,400 square yards of this pavement. About one-half consists of one course of vitrified brick laid on edge on a foundation of 8 inches of Louisville cement concrete, a sand cushion $1\frac{1}{2}$ inches thick intervening between the brick and the concrete. The remainder consists of two courses of brick, the lower course laid flat on 2 inches of sand, with which the spaces between the bricks were thoroughly filled. This course was then covered with a sand cushion $1\frac{1}{2}$ inches thick, on which the wearing course of brick was laid on edge.

In both cases, after laying, the pavement was thoroughly rolled with a heavy roller. It was then carefully examined and all broken and defective bricks were replaced with sound ones. The pavement was then again rolled and all interstices between the bricks were filled as thoroughly as possible with sand. A layer of sand about $\frac{1}{2}$ inch in depth being finally spread over the top, to be worked in by the travel. For both classes of this pavement the ground was prepared by rolling, and, where filling was required, cinders were used, as being the best material available for that purpose. The cinders were thoroughly compacted by rolling with a heavy roller, all low spots being brought up to grade and re-rolled. In this part of the work the greatest care was used to insure a good foundation. The vitrified brick came from Galesburg, Illinois, and seemed carefully made and thoroughly burned. In the

double-course pavement, the lower course was laid with seconds. It has now been in use since March 4th of this year and has proved entirely satisfactory. Being laid in a yard devoted to heavy teaming, it is subjected to a severe test, and I believe it will stand it. In doing the work thus thoroughly throughout the object has been partly to furnish a test piece, and I think the municipal authorities should watch this pavement with interest, and appreciate the work of the company in making this experiment for them.

At Franklin Avenue and First Street, and extending north to Carr Street, is located the freight house of the company. At the South end, facing Franklin Avenue, is the office building, 141 feet 6 inches front and 38 feet deep, built of brick, laid in Portland cement. The floors are of mill construction, carried on iron girders, except the first floor, which is granitoid, on brick arches turned between the girders. The walls are made of sufficient strength for a seven-story building, in case it should ever be required, but only four stories have thus far been constructed. Just north of and adjoining the office building is the freight house proper, an iron frame building with foundation of stone and brick, 770 feet long and 131 feet 10 inches wide, with five tracks in the house, giving a capacity of one hundred cars. The delivery platform is on the east and the receiving platform on the west side. Owing to the difference in the level of the streets on the two sides of the freight house, it was necessary to build the platforms on a grade sloping towards the east, but, as everything is handled to and from the cars down this grade, this has proved rather a benefit than otherwise. North of the freight house, and extending to Carr Street, are open platforms, with granitoid floors, 76 feet long, each provided with a crane for handling heavy articles, such as machinery and boilers. Just north of Carr Street is a small yard, with a capacity of thirty-two cars, for handling car-load freight, and the drive-ways of this yard are also paved with vitrified brick.

The most important structure on the line of the St. Louis Extension is the Bellefontaine Bridge, across the Missouri River. This is a double track bridge, with four main spans of 440 feet each, center to center of end pins: supported on heavy masonry piers, and with a viaduct approach, 850 feet in length, on the north side of the river. Beyond the approach is a timber trestle, 2,960 feet in length, which is now being filled in. The main river spans are single-intersection Pratt trusses, divided into eight panels of 55 feet each. The trusses are designed for a rolling load of 3,000 pounds per foot on each track. These spans are built without any adjustable members, the top and bottom laterals are all riveted, and the reversal of strains at the centers of the trusses is effected by so constructing the inclined web members that they shall resist compression as well as tension, instead of using the usual adjust-

CROSBY—ST. LOUIS EXTENSION OF THE ST. L., K. & N. W. R. R.

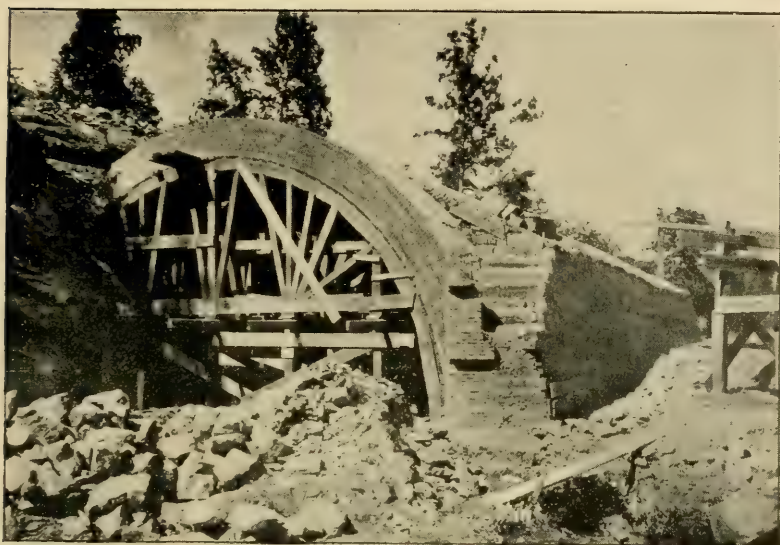


FIG. 3.—COLDWATER ARCH, AUGUST 20, 1893.



FIG. 4.—COLDWATER ARCH, DECEMBER 14, 1894.

CROSBY—ST. LOUIS EXTENSION OF THE ST. L., K. & N. W. R. R.



FIG. 5.—BELLEFONTAINE BRIDGE ACROSS MISSOURI RIVER.

able counter ties. These spans are built throughout of steel, except the bed plates on the piers, which are of cast iron. The steel work was manufactured by the New Jersey Steel and Iron Co., of Trenton, N. J., and erected by Wm. Baird, of Pittsburg.

The viaduct approach is a riveted steel structure, with alternate spans of 28 feet 6 inches and of 32 feet 2 inches. It rests on small piers of brick, which will be described later. The steel work of the viaduct was furnished and erected by Messrs. A. & P. Roberts & Co., of Pencoyd Iron Works, Philadelphia.

The substructure for the main bridge consists of four piers and an abutment. This abutment is founded on solid rock on the south bank of the river at about the level of extreme high water. The piers are all founded on pneumatic caissons, which are, with one exception, sunk to the bed rock of the river. They are numbered from south to north, the abutment being Pier I.

The masonry of the piers is built of oolitic limestone from Bedford and Romona, in Indiana, except that in Piers II, III and IV, for about thirty feet, covering the range between extreme high and low water, the face stones are of Minnesota granite. All of the face stones are set in Portland cement. The backing consists of large stone, cut to the same rise as the courses in which they are laid, and with both top and bottom beds dressed. The specifications required that the spaces between these large backing stones should occupy not more than 20 per cent. of the area inside of the face stones; but, in fact, as the masonry was laid, they occupy in most instances not more than 10 per cent. of that area. All such spaces were filled with concrete, thoroughly rammed into place. These backing stones were so laid as to break bond in the different courses. The backing was laid in Louisville cement mortar, except in freezing weather, when Portland cement was used throughout. After the masonry in the piers was laid, all face joints were cleaned out to a depth of $1\frac{1}{2}$ inches, and pointed with Portland cement mortar, in the proportion of 1 part cement to 2 of sand, driven in with calking irons. The masonry of these piers is a very fine piece of work, and, I think, the best I have ever seen.

The work was done, under contract, by Messrs. Christie & Lowe, of Chicago; Mr. George A. Lederle was the resident partner. The contractors furnished all materials and tools, except cement, which was furnished by the railroad company. There were 11,022 yards of this masonry, and there were used in setting it 1,620 barrels of Portland cement and 1,566 barrels of Louisville cement. The price paid the contractors was \$17 per cubic yard, and the average cost, including everything, was \$17.75.

All of the foundation work was done by the company's men, under

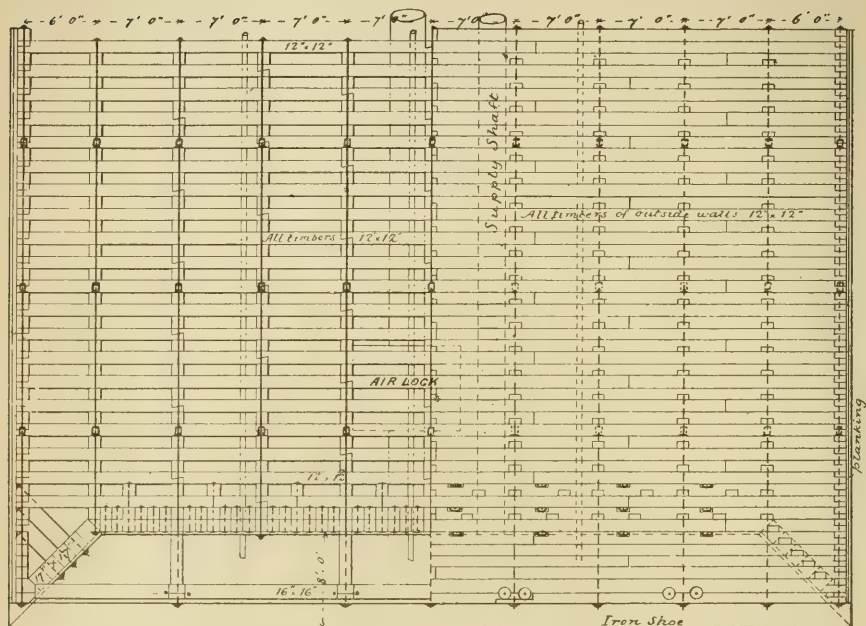


FIG. 6.

LONGITUDINAL SECTION
AT CENTRE.

SIDE ELEVATION UNDER
PLANKING.

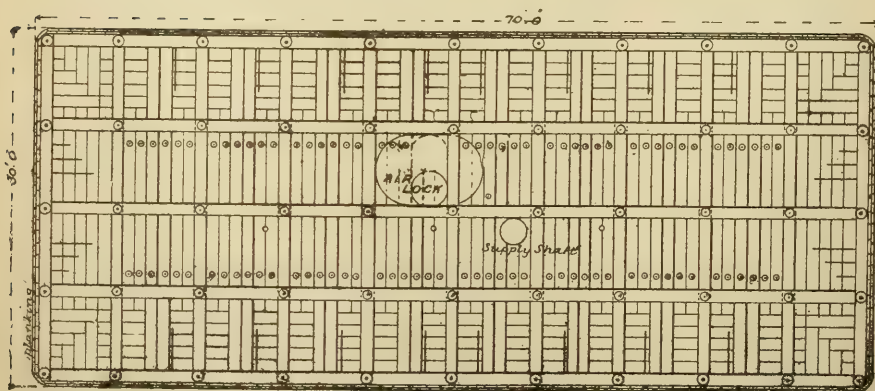


FIG. 7.—PLAN ON TOP.



FIG. 8.

CROSS SECTION
AT CENTRE.END ELEVATION
UNDER PLANKING.

FIGS. 6, 7 and 8.
CAISSON AND CRIB WORK
OF CAIRO BRIDGE.

the direction of the Resident Engineer. The work was handled under rather more than ordinary difficulties, owing to the fact that during the greater part of the time that the foundation work was in progress there was no railroad communication with the bridge, and all material and supplies had to be brought up the river on barges, which added considerably to the expense and was a constant source of worry to those in charge of the work, especially during the extreme low stage of water which prevailed in the fall of 1892. To prepare for the early winter, when the river was liable to be blocked with ice, a large supply of coal had to be procured and stored; and, notwithstanding the precaution taken in this direction, there was less than ten hours' supply on hand when the track from the north finally reached the bridge in January, 1893, so that coal could be received by train.

There being no town or village in the neighborhood, it was necessary to erect boarding-houses and all other buildings required for the accommodation of the men and for the storing of materials.

The four piers in the river are founded on pneumatic caissons, those for Piers II, III, and IV being 70 feet long by 30 feet wide, and that for Pier V, 60 feet long by 24 feet wide. They are identical, in construction, and in form, except as to height, with those used at the Cairo bridge, and illustrated in Figs. 6, 7 and 8, reproduced from Vol. IX, No. 6, of this JOURNAL, June, 1890, pages 314 and 315.* All the caissons were 16 feet high, including the iron cutting edge, and were surmounted with a wooden crib-work, constructed like the upper portion of the caisson proper. This crib-work was 24.4 feet high in Pier II, 45 feet in Pier III, 58 feet in Pier IV, and 64 feet in Pier V. The crib-work was filled with concrete, Louisville cement being generally used in the proportion of 1 part cement, 2 of sand, and 4 of crushed stone; but, in certain portions of the work, and at all times in freezing weather, Portland cement was used, generally in the proportions of 1 part cement, 3 of sand, and 5 of crushed stone. The form of caisson employed was that which has generally been used by Mr. Morison on his works, with an iron cutting edge, vertical outside walls of 12 by 12-inch timber, and the working chamber walls inclined inwards on an angle of 45° , supported by iron rods running through the outside walls. In the larger caissons, there were in the working chamber four transverse braces of 16 by 16-inch timber, and also a longitudinal timber of the same size. In the smaller caisson, the longitudinal timber was omitted, and there were only two transverse timbers. The inside of the chamber was lined with 3-inch plank, and then carefully caulked. The caissons throughout were built of long-leaf yellow pine.

* These cuts are kindly furnished by Mr. John W. Weston, ex-Secretary, Ass'n Eng. Socs.—*Secretary.*

The pneumatic plant used for sinking the caissons consisted of two No. 4 Clayton duplex compressors, having steam and air cylinders, each 14-inch, with 15-inch stroke; a Worthington duplex pump, 18½ by 10½ by 10 inches, and a small dynamo, run by a Westinghouse automatic engine for lighting the working chamber. This plant was set up on the steamer John Bertram, whose boilers furnished the power to run the plant. There was also a duplicate plant, which was used during part of the work on Piers II and III, when there was not water enough to reach those piers with the steamboat. This plant was erected on a platform, supported on piles just below Pier III. In addition to the above, there were several hoisting-engines, a pile-driver boat, provided with a derrick for handling the timber in building up the crib-work and an arc-light plant for night work. As far as possible, the concrete was mixed by machine, a Cockburn barrow mixer being used, which was set up on a large barge, with a derrick for handling the concrete buckets. Several other barges for handling timber, cement and crushed stone were provided, and a small steamboat for towing the barges.

A short account of the work on some of the piers, and of some of the difficulties encountered, will probably be of interest. All of the caissons, except that for Pier II, were built on launching ways on the north side of the river just above the bridge line. These launching ways were constructed by driving piles, which were capped with 12 by 12-inch timber running up and down stream, and then the way timbers, also 12 by 12, were put in position and securely drift-bolted. The ways had a slope toward the river of 3 inches to the foot, and were extended out into the river far enough to allow the caisson to float before being clear of the timbers. The piles under water were cut off by a circular saw hung in a frame attached to the leads of the pile-driver, the caps were set in position by a diver, and the drift-bolts, which had been started into the caps before they were sunk, were driven by a ramrod working through a gas-pipe placed over the drift-bolt.

The cutting edge for Pier III was set up on July 30, 1892, and the building of the caisson proper was completed and the caisson successfully launched on August 20th. In the meantime, sandbars had formed at the site of the pier, so that there were only from two to five feet of water, and the caisson, after launching, drew ten feet. However, it had to be got into position, if possible, and this was accomplished as follows: The steamer John Bertram was taken over to the pier site and made fast to piles driven for that purpose, and her wheels were set to work to wash out the sand. This proved a success, a hole from seven to ten feet deep being dug out at the site of the pier. In the meantime, barges had been placed on each side of the caisson, and heavy timbers bolted across the caisson, and extending out over the barges. On the morning of

August 3d, the John Bertram was brought back to the shore, and fastened behind the caisson, which it proceeded to tow across the river until it struck bottom, when the air pumps were started and air pumped into the caisson, raising it until it drew only about five feet of water. As the caisson was raised, blocking was placed under the timbers projecting over the barges, to keep it level, and without further difficulty it was towed to its proper position, the air was released and the caisson was let down upon the sand. After this, the work was carried on without further difficulty, except that the caisson was abandoned from September 21st until December 3d, while the second plant was being erected, the water at the pier having become so shallow that the steamer had to be removed on the former date. This caisson finally reached the bed rock on January 2, 1893, at a depth of 88.80 feet below standard low water. The work of filling the chamber with concrete was completed on January 11th. The material was excavated and discharged from the working chamber by the Morison sand pump, a modification of the Eads sand pump used on the St. Louis Bridge. On this pier, and also on Pier IV, an elevator was provided for taking the men up and down the shaft. The air lock, Fig. 9, was placed at the top of the caisson proper, with a short shaft leading down into the chamber. Above the lock was a shaft six feet in diameter, provided with guides, on which the elevator ran, being raised and lowered by an engine placed on top of the shaft, and driven by the compressed air taken from the caisson. This elevator proved a great relief to the men, and it would have been a great convenience if we had had one on each of the piers.

The caisson for Pier IV was launched on September 20th, and on the 24th the caisson was towed out into position and securely fastened to four clusters of anchor piles, near the four corners. By means of lines leading from these clusters of piles it was held accurately in position as it sunk down to the sand. When the caisson was placed in position on the 24th, soundings showed fourteen feet of water at the west end and thirteen feet at the east end. The work of building up the cribbing was started that night, and continued till the 29th, when concreting commenced. At this time, soundings showed about twenty feet of water all around the caisson, which was still afloat. As the weight of the concrete settled the caisson, the current gradually cut away the sand below; and on the morning of the 30th, there was an average of twenty-three feet of water all around, with 25.5 at the northwest corner. At about 3 p.m. of that day the caisson grounded on the south side, and on the morning of the 1st of October, it was still aground on the south side, but on the north side there were about twenty-five feet of water, with twenty-six feet at the northwest corner. About six hundred bags of sand were thrown in at the west or up-stream end, in order to cut off

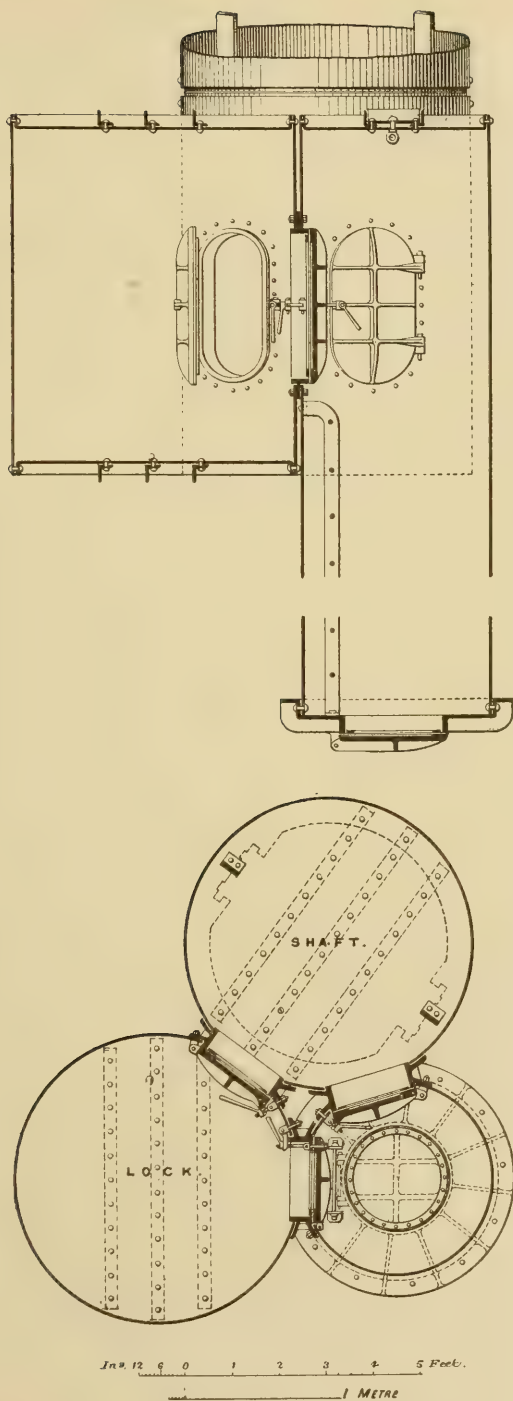


FIG. 9.—AIR-LOCK AND SHAFT FOR PIERS III AND IV.

the current, and with some success, for on the morning of the 2d, the caisson was found to be aground on sacks at the west end. Concreting was continued during the 2d and 3d, and during the afternoon of the 3d more sand bags were thrown in along the north side, as the sand had again started cutting there. On the morning of the 4th, the air pipes were connected and the air pressure was put on.

On attempting to enter the caisson through the air-lock, the door of the main shaft below the lock was found to be blocked up underneath, so that it could be opened only a few inches, and it was impossible to enter in that way. The pressure was let off the caisson, a man was lowered into one of the supply shafts used for taking in the concrete filling of the chamber, the top was put on the shaft again and air pressure was once more turned on the caisson. The man sent into the caisson found that a part of the temporary false bottom that had been used in launching it, had not been removed, and that some of the timbers were jammed up against the main shaft door. These he soon cleared away and the caisson could then be entered through the lock. The writer went down to make an examination, and found that along the south side and east end the caisson was filled with sand nearly to the roof, while along the north side and west end it was far below the cutting edge. Some of the false bottom had become wedged under the cross-beams, and as weight was put on the caisson above it was pressed down, and the cross-beams supported most of the weight of caisson and concrete; the result being that all of the cross-beams were split and most of the vertical posts between them and the roof were either shoved up into the roof or down into the beams, the worst point being at the second cross-beam from the down-stream end, where the beam was shoved up so that the distance between it and the roof was only 3 feet 4 inches, instead of 4 feet, as originally built. The vertical post at the center was split through its entire length, and crushed down into the longitudinal beam.

Concreting was at once stopped, so as to add no further weight, and men were set to leveling down the sand in order to bring the bearing on the cutting edge all around, and to clear out under the beams, so as to relieve the pressure on them. When this was done, the beam that had been pushed up eight inches came back to within three inches of its original position. As soon as everything was cleared up the cracked beams were jacked down into place and securely bolted, new posts were put in alongside the old ones that had been damaged, and the work went on as usual. On November 18th this caisson reached the bed rock at a depth of 101.1 feet below standard low water, and the concrete filling was completed on the 30th. In this pier, on top of the bed rock, was found a layer over two feet deep of cobble stones and boulders, most of which were worked into the concrete, but had to be handled so much

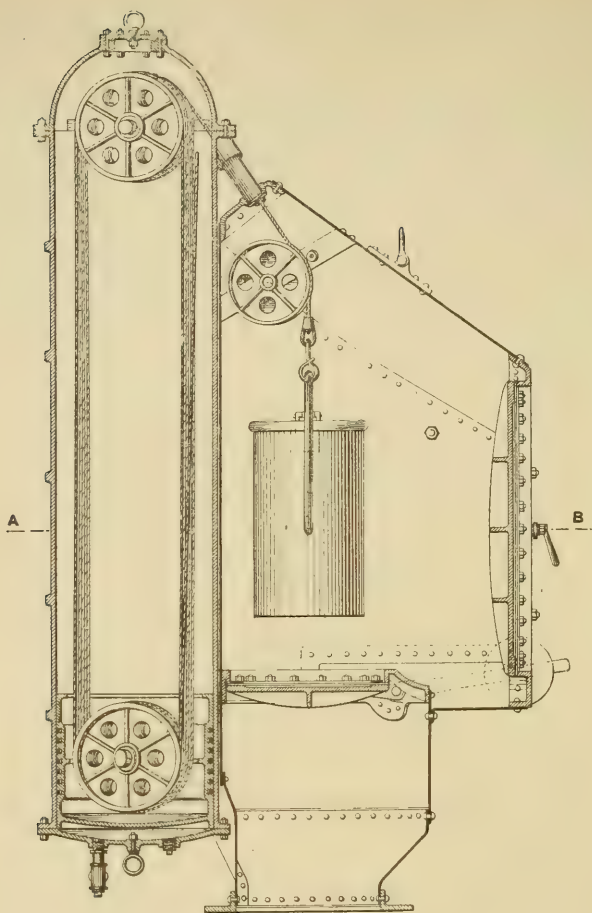
that they made the work of concreting slow and expensive, especially as the men were working about one hour at a shift, and from two to three hours for a day's work, at \$3.50 per day.

The caisson for Pier V was launched December 11th, and reached its final resting-place, 82.6 below standard low water, on March 7, 1893. It was not sunk to bed rock, but was stopped in sand. As it comes within the permanent shore line, where the caisson will always be surrounded with sand, so that there can be no danger of scour, it was considered perfectly safe to leave it on the sand. The rock at this point was 109 feet below low water, and we would have had to work with a submersion of at least 112 feet. It was, therefore, not considered best to take the additional risk where it was not really necessary. The total weight of this pier, taking the timber at 50 pounds per cubic foot, concrete at 145 pounds, and masonry at 160 pounds, which weights, I believe, to be rather in excess of the actual, is :

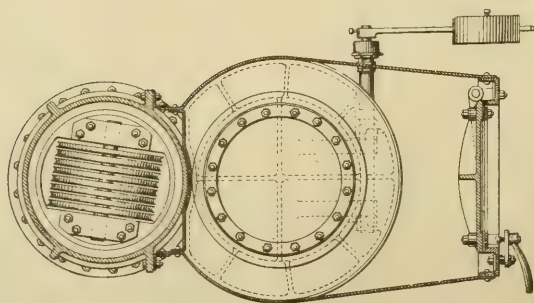
	9,864 tons.
It carries one-half of the 400 foot span	700 "
Making a total, with bridge unloaded, of	10,564 "
With both tracks loaded with 3,000 pounds per foot.	660 "
We have in all	11,224 "
From this should be deducted the weight of water displaced, or	3,784 "
Leaving	7,240 "

which, on the bottom area of 1440 square feet, would make a pressure of practically five tons per square foot, which is not excessive. This is figured at standard low water, and no account is taken of the friction on the sides of the caisson. If this is taken into account, the pressure on the bottom of the foundation is reduced to a very low amount.

The caisson for Pier II was built in position on the sand bar. Borings made at the site of this pier showed that the bed rock dipped to the north about seven feet in the width of the caisson, making it necessary to excavate and hoist a considerable portion of the rock. For this purpose a Morison clay hoist, Fig. 10, was provided. This hoist was originally designed for use on the foundations of the bridge over the Missouri River at Rulo, Nebraska. It employs an air-lock set on top of the concrete supply shaft. On the back of this air-lock is bolted a cylinder with a diameter of 18 inches and stroke of about 9 feet, connected with the air-lock near the top by a pipe 3 inches in diameter. In the top of the cylinder is placed a set of sheaves, and in the top of the piston, which is in the cylinder, is fastened another set of sheaves. Over these sheaves is run a wire rope, which is then led through the connecting



SECTION THROUGH CENTRE.



SECTION AT A. B.

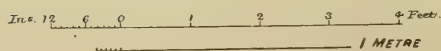


FIG. 10.—MORISON CLAY-HOIST.

pipe to the air-lock and over a sheave which hangs over the center of the shaft. The bottom door of the air-lock is hung on a shaft, which passes out through a stuffing box in the side of the lock so that the door can be worked from the outside. The bottom of the cylinder is connected with the air pipe of the caisson by pipes provided with the necessary regulating valves. A bucket being hung on a hook at the end of the rope, the outer door of the lock is closed and the air pressure is let into the lock until it is equal to that in the caisson below, when the bottom door is opened from the outside. Air pressure is then admitted to the cylinder and as the air pressure under the piston is equalized with the pressure in the caisson the weight of the bucket overhauls the piston and the bucket is lowered to the bottom, where a full bucket is hooked on and hoisted by allowing the air to escape from under the piston, when the caisson pressure on the top of the piston, which comes back through the connecting pipe, forces the piston down and raises the bucket, the bottom door being closed, the pressure in the lock is equalized to the normal pressure, the door is opened and the bucket is dumped.

The sinking of this caisson presented no difficulty, except that occasioned by encountering some oak logs, until rock was reached on the south side, at a distance of 62 feet below standard low water, through which the caisson was carried down to a depth of 68.4 feet below standard low water. On the north side the cutting edge did not reach the rock, except for a short distance near the northwest corner, but blocking was put under the shoulder of the cutting edge to support the caisson, and the rock was entirely cleared off, so that the concrete filling was placed on the entire surface of the rock. At the northeast corner of the caisson the concrete was carried down to a level more than two feet below the cutting edge. The writer personally superintended this piece of work, and he knows that it was thoroughly done. The rock was broken up by blasting. The explosive used was racka-rock, which has an advantage over dynamite for such work in not producing the violent headache which the latter generally causes, especially in a confined place like a caisson. To avoid danger of damaging the caisson, only light charges were used, and the explosive proved satisfactory.

During the filling of the chamber with concrete there was a sharp rise in the river, which completely submerged the pier, only the shafts and pipes being left above water; and they were protected from injury from drift logs by a bulwark of bags of crushed stone built up on the nose of the pier and carried down to and around the shafts. During the last day or two the water was five feet deep over the masonry of the pier.

There were used in the construction of these caissons 1,608,814 feet

B. M. of yellow pine timber. The cost of framing this timber and building it into the caissons averaged \$21.93 per M. B. M. This includes cost of launching ways and of material and labor of all kinds, except the cost of the timber itself. It includes also all handling and towing.

There were placed in these caissons 13,285 cubic yards of concrete, in which were used 4,759 barrels of Portland cement and 16,035 barrels of Louisville cement. The average cost of this concrete, including all material and labor, was \$5.36 per cubic yard. The average cost per cubic foot of caisson and filling, including cutting edges, shafting, etc., was 34.2 cents. The average cost of sinking was 9.17 cents per cubic foot sunk, this average being materially increased by the cost of the rock excavation in Pier II, the average cost for that pier being 12.33 cents. The average per vertical foot sunk was \$177.99. Pier II affected this average also, as it cost \$258.94, while Pier V cost only \$116.17 per foot sunk.

The piers for the viaduct approach were built of vitrified brick laid in Portland cement, and were finished with heavy cast-iron caps. These piers are circular, with a diameter of 5 feet, and they rest on a foundation of Portland cement concrete supported on seven oak piles extending 3 feet into the concrete. This concrete foundation was 5 feet deep, built in the form of a hexagon, with sides of 5 feet. The brickwork was 8 feet in diameter, where it started from the concrete, and tapered to 5 feet in a rise of 3 feet 10 inches. The anchor rods were made in the shape of a U, and extended down through the brickwork and for 3 feet into the concrete. At the north end of the viaduct was built a small masonry pier of Romona limestone. This pier rested on a foundation of Portland cement concrete 10 feet thick, supported by 40 oak piles, which extended 6 feet up into the concrete. With the exception of the limestone masonry, this work was all done by the company's men, under the direction of the Resident Engineer.

The cost of pile driving, including unloading and distributing piles, and all fuel, rope, and material of all kinds, was $21\frac{1}{2}$ cents per linear foot. This rather high cost was largely due to delays in waiting for piles.

The cost of the concrete was \$8.48 per cubic yard, including all labor and material and the necessary forms used. This cost is also high, but the mixing was all done by hand, and the material had to be hauled a long distance. It was carefully put in and it can be relied upon.

The timber trestle was also put in by the company's men. As this trestle was to be filled immediately, the specification for the timber was not very rigid, no objection being made to sap, but it was required to be sound and free from wane. Soft wood piles were used. With this exception the trestle was built as if it were to last for years, and was very

thoroughly braced, both longitudinally and transversely. There were 1,437,763 feet B. M. of Southern pine timber used in this trestle, 97,552 pounds of iron and 35,220 linear feet of piles.

The cost of unloading, handling and driving piles, including all material and labor, except the cost of piles themselves, was 13.7 cents per linear foot.

The cost of unloading, framing and erecting timber, including all material and labor, was \$7.42 per M. B. M.

In addition to the work described there was considerable work done on shore protection. This included the revetment of about 2,000 feet of bank above the bridge, with a woven willow mattress, which was from 125 to 200 feet in width. This mattress was sunk and covered with rip-rap. Before weaving the mattress, the bank was prepared with a slope of three to one, the excavation being done by hydraulic grading and the power being furnished by the Worthington pump on the steamer John Bertram. This proved a very satisfactory and economical way of doing the work, and I regret that I am unable to give any exact figures of the cost. The shore protection also included a pile dike, about 1,100 feet long, extending down past and outside of Pier V. The piles were driven through a sill mattress 100 feet wide, extending 75 feet outside of the piles. This mattress is built in the form used by the United States Government Engineers on the lower Mississippi River, being composed of fascines of brush between frames of poles, and the whole is securely fastened with wire. This dike has withstood a flood which was up to the tops of the stringers, and with the strongest current in the river running along it. Those familiar with the Missouri will know that without the sill mattress the piles would not have stood an hour.

The first engine passed over the bridge on December 27, 1893, and the structure was opened for traffic on March 4, 1894.

MEASUREMENT OF WATER.

Report to the Montana Society of Civil Engineers.

By A. M. RYON, COMMITTEE ON THE MEASUREMENT OF WATER FOR IRRIGATION
AND MINING.

[Read November 10, 1894.]

IN the early days of mining and farming in this State, as in others, some easily applied approximate method for the measurement of water was found to be necessary; for this purpose an orifice of prescribed dimensions with a certain head was agreed upon, and the flow through the opening divided by the area of the opening, expressed in inches, gave what is called a "miner's inch." So long as rough approximations were sufficient, this device served the purpose; but, as the demand is an increasing one while the source of supply is practically constant, the time will come, and indeed it has come in many localities, when a more accurate measuring device will be needed in order to insure a fair and economical distribution of our water. Section 1,262 of the Compiled Statutes of Montana reads:

"The measurement of water appropriated under this chapter shall be conducted in the following manner: A box or flume shall be constructed with a head-gate placed so as to leave an opening of six inches between the bottom of the box or flume and lower edge of the head-gate, with a slide to enter at one side of and of sufficient width to close the opening left by the head-gate, by means of which the dimensions of the opening are to be adjusted. The box or flume shall be placed level, and so arranged that the stream in passing through the aperture is not obstructed by back water, or an eddy below the gate; but before entering the opening to be measured the stream shall be brought to an eddy, and shall stand three inches on the head-gate and above the opening. The number of square inches contained in the opening shall be the measure of inches of water."

As has already been pointed out in your meeting of December, 1893, this section is unsatisfactory.

We do not understand exactly what is meant here by the term "eddy," as no definition of that word will fit in the sentence and make sense. If it is intended, as many suppose, that the water shall be brought to a standstill before passing through the orifice, we have an impossible condition. The water is to "stand three inches on the head-gate and above the opening;" this is ambiguous. An engineer would naturally conclude that the measurement was to be taken, as is cus-

tomary, at a distance of several feet up the stream from the opening, but I have been assured by a lawyer that it should be measured directly above the opening; although just how this measurement can be accurately taken is not apparent. Our experiments show that on an opening about forty-two inches long the depression of the surface of the water directly over the opening would approximate one-half inch more or less. This was determined by placing a straight edge on the surface of the water at that point. If the lowest point of this depression measured three inches in height over the top of the opening, the actual head would then be about three and one-half inches instead of three inches, giving the owner of 250 inches something like ten per cent. the advantage over the owner of say 50 or 100 inches.

Nothing is said regarding the thickness of the plank enclosing the opening. Our observations lead us to believe that up to two inches, at least, the escaping jet touches only the inner edge on three sides. On the upper side the stream is in contact with the entire thickness of the plank, but I doubt whether any perceptible error is introduced on this account. If the plank is made sufficiently thick to suppress the contraction of the escaping jet, we may look for an increased discharge. The same increase may be obtained by prolonging the edges with boards so that the length of the box so formed shall be say two or three times its least dimension.

The law does not specifically prohibit the use of curved entrance to the orifice, and this we know would increase the flow to a very marked extent. If the ends of the opening coincide with the sides of the box, we get a partial suppression of the contraction of the escaping jet and consequently an increased flow. Lack of time prevented us from showing by experiment exactly what this would amount to, but past experiments on weirs show that this suppression is a very important factor in increasing the discharge. In the case of a weir two feet long with a head of six inches the increase would be about five per cent. Where conoidal mouthpieces have been used, Francis (Lowell Experiments) obtained a coefficient of 0.94 with a head of 1.52 feet; Unwin (*Philosophical Magazine*, October, 1878), with heads of from 0.98 foot to 1.4 feet, obtained coefficients as high as 0.991, almost the theoretical flow, an increase of about sixty-six per cent. over the ordinary rectangular opening; Castel (*Annales des Mines*, 1836), with heads of from 0.75 foot to 1 foot, obtained a coefficient of 0.956. These examples are mentioned merely to show the possibilities which attend the alteration of the conditions under which the discharge takes place, and to impress the necessity of defining exactly what conditions shall be adhered to when appropriated water is to be measured.

Although many experiments on the flow of water through orifices,

notably those by Lesbros, Hamilton Smith, Jr., Ellis, Francis, Unwin, Steckel, Bazin and Castel, are on record, the majority were made with circular orifices, and none of them are suitable for obtaining close results under the conditions prescribed by our Montana law. My experiments were made with the object of determining the amount of water in cubic feet per second represented by a miner's inch, measured according to the Montana statute, through openings of various widths, without suppression of end contractions, and to deduce a series of coefficients for rectangular orifices 0.5 foot high and of variable width, with a head of 0.5 foot over

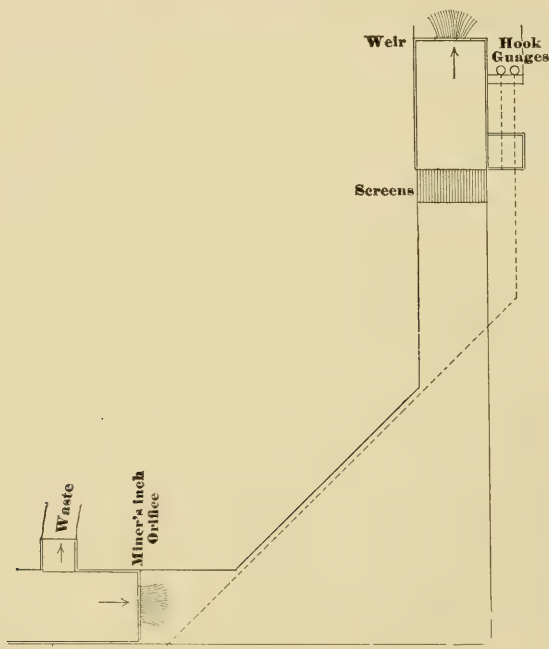


FIG. 1. PLAN SHOWING ARRANGEMENT OF APPARATUS.

Scale, 1 inch = 12 feet, or $\frac{1}{12}$.

the center. The coefficients so deduced are to be used in the formula $Q = c a (2gh)^{\frac{1}{2}}$. The experiments were intended to cover a range of from 36 to 252 miner's inches, the available water supply not allowing of larger measurements. Owing to formation of waves in the approaching water, when the opening exceeded six inches wide by thirty inches long, all measurements made on larger openings than this were rejected as being unreliable. It is to be regretted that owing to the shortness of the time during which the water could be obtained, this difficulty could not be remedied. After passing through the orifice, the water was measured by passing it over a weir two feet long. The soil in the channel

between the orifice and the weir consists largely of clay, and, after being soaked with water for several days, admits of practically no percolation. This was demonstrated by allowing the water to stand in the channel above the orifice.

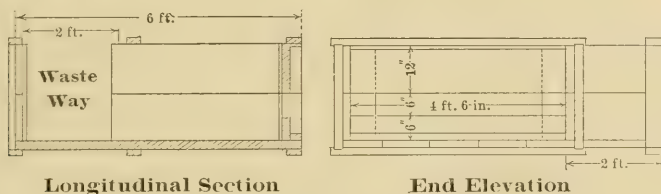


FIG. 2. MINER'S INCH ORIFICE.

Scale, 1 inch = 4 feet, or $\frac{1}{4}$.

There was a slight leakage in the box enclosing the weir; but, as it appeared on the side where the hook gauges were located, there was no difficulty in measuring it approximately with a small weir. The leakage varied from 0.0031 to 0.0087 cubic foot per second, according to the depth on the weir, and was added to the flow over the weir. No difficulty was experienced in obtaining smooth water, free from eddies, in the weir box. The heads were measured with a hook gauge reading

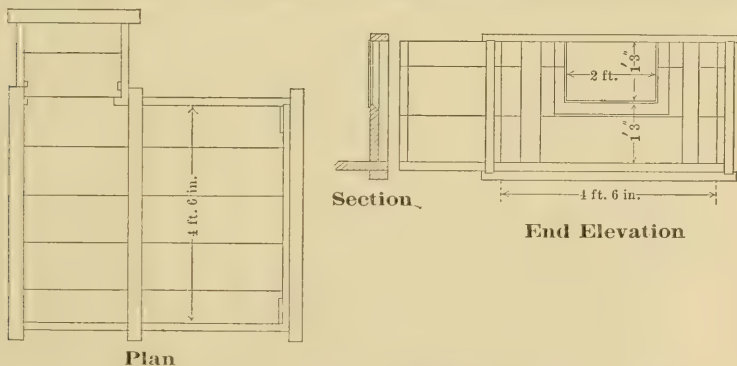


FIG. 3. WEIR.

Scale, 1 inch = 4 feet, or $\frac{1}{4}$.

to 0.001 of a foot and taken at points six feet back of the openings. The weir box was built with a space two feet square on the side; this space is to be used in the future for holding a float for a Carpenter Register, and is separated from the main box by planking carried to within one inch of the bottom. The head was taken from the orifice box through a hole one inch in diameter bored perpendicular to the side, about six feet back of the orifice, near the bottom, and communicating with the hook gauge through a galvanized iron pipe three quarters of an inch in diameter.

An attempt was made to imitate as far as possible the usual practice in the construction and use of a miner's inch measuring device. The openings for the orifice measurements were made by placing vertically planks one inch thick and of various widths, so that the pressure of the water would hold them against the end of the box. The end of the box was made by placing two planks, two inches thick, horizontally, with a space of six inches between them (as shown in Fig. 2). Owing to a slight settlement of the weir box when it contained water, levels were taken from the crest to the hook with almost every reading.

The practice of taking several readings within a stated time and reducing them to a mean head, was not followed here; but we allowed the water to rise very slowly on the orifice hook, regulating the rise by the waste gate Fig. 1. Another waste gate farther up the stream regulated the flow approximately.

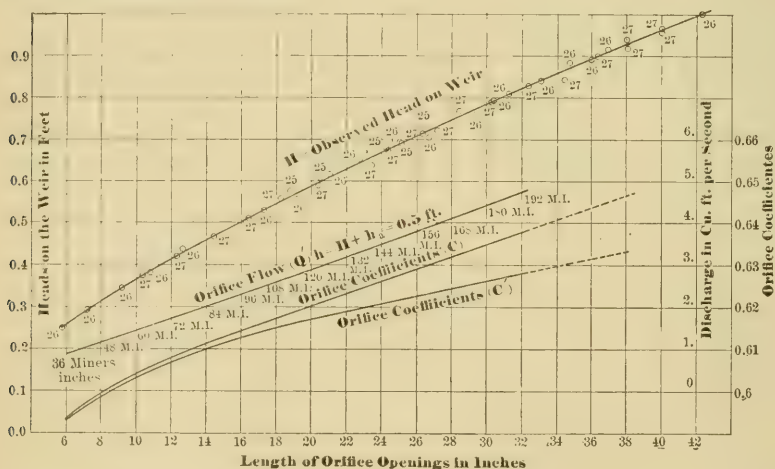


FIG. 4. DIAGRAM OF RESULTS.

$$\begin{aligned}
 Q &= C \times 0.5 \times l \sqrt{2gH} \\
 Q' &= C' \times 0.5 \times l \sqrt{2g(H + h_a)} \\
 \sqrt{2g} &= 8.02.
 \end{aligned}
 \left. \begin{array}{l} \\ \\ \end{array} \right\} \begin{array}{l} \text{Discharge in cubic feet} \\ \text{per second.} \end{array}$$

$T = 40^\circ \text{ to } 50^\circ \text{ Fahr.}$
 $H = \text{observed head.}$
 $h_a = \text{head due to velocity of approach.}$
 $C = \text{coefficient.}$
 $C' = \text{coefficient corrected for velocity of approach.}$
 $l = \text{length.}$

The numbers shown on the upper curve refer to the dates on which the experiments were made.

The observed weir heads for different lengths of orifices are plotted in Fig. 4, and a curve is drawn through these observed heads.

All calculations for flow are based on this curve, which is subsequently corrected for leakage and for velocity of approach. The correction for velocity of approach was made as follows: $h = H + 1.4 V_a^2 \div 2g$, in which H = observed head, V_a = velocity of approach and g = acceleration of gravity. Smith's formula, $Q = c \frac{2}{3} l (2gh)^{\frac{3}{2}}$, was used, h being the observed head H plus the head h_a causing the velocity of approach.

Smith's curve of coefficients for a weir two feet long, with contractions, was drawn from data principally supplied by Fteley and Stearn's experiments with a weir three feet long, with heads from 0.6 foot to 0.95 foot; Francis' experiments with a weir four feet long with heads from 0.7 foot to 1 foot; Smith's experiments on weir two feet and six inches long with heads from 0.6 foot to 1.7 feet; and Lesbros' experiments on a weir 1.97 feet long with heads from 0.4 foot to 1.4 feet. These experiments give insufficient data for a very precise location of the coefficient curve for weirs two feet long with heads of from 0.1 foot to 0.5 foot, and the writer believes that the results given are a little high, possibly averaging one-half per cent., as in deducing a curve of orifice coefficients a lack of uniformity was observed between those places, the results being higher than would be expected, assuming the remainder of the deduced curve, which was fairly uniform, to be correct. Francis' formula between these heads, on the contrary, gave results somewhat lower than one would expect; but Francis' experiments were made on longer weirs, and it is not claimed that his formula holds good for short weirs, especially where the head is greater than one quarter the length of the weir. Cippoletti claims that Francis' formula gives results about one per cent. too low.

The coefficient curve for the orifices as drawn by the writer therefore lies between the points indicated by the use of Smith's formula with his weir coefficients, and Francis' formula for measured heads of 0.5 foot and under, while it coincides with the points indicated by Smith's formula, where the measured heads were above 0.5 foot. To insure perfect contraction, according to Smith, the distance from the ends of the weir to the sides of the box should be at least $3h$, while a distance of $2h$ might introduce an error of one-half per cent. This latter condition is fulfilled in measuring water coming from orifices up to twenty-two inches in length. The distance from the crest of the weir to the bottom of the box was 1.24 feet. The weir edges were made of two inch by one-sixteenth iron screwed to the woodwork, which consisted of two-inch plank firmly braced. The temperature of the water was between 40°F . and 50°F . during the experiments; and $(2g)^{\frac{1}{2}}$, corrected for altitude and latitude, was taken at 8.02.

Fig. 4 shows the curve of observed heads: a curve of orifice coeffi-

cients without allowance for the head producing the velocity of approach; a curve of orifice coefficients deduced for a head: $(H + h_a) = 0.5$ foot, and a curve indicating the total discharge in cubic feet per second from the orifices, with the corrected coefficients. It will be seen that, unless the velocity of approach is considered in the case of an orifice 6 inches wide and 30 inches long, under the conditions assumed, an increased flow of 1.46 per cent. is obtained; this amount decreases as the area of the orifice decreases in proportion to the area of cross-section of the approaching channel.

Mr. Hamilton Smith, Jr., made three experiments to determine the value of a California miner's inch. The plank used was 3 inches thick, and was beveled to 1 inch at the orifice. The contraction touched only the inside edge and the corners. The results of his experiments are given below.

Eureka Lake Standard Orifice, 50 inches long, 2 inches wide, 6 inches head above top of opening. Full contraction. Temperature of water about 65° . $(2g)^{\frac{1}{2}} = 8.018$. Size of opening: length, 4.1667 feet; width, 0.16667 foot. Head, 0.5833 foot. Discharge in cubic feet per second, 2.618. C 0.6156, c 0.6161.

Mr. Smith also made experiments with the North Bloomfield Standard called 200 miner's inches. $12\frac{3}{4}$ inches long, 6 inches head above the top of the opening, 12 inches wide, plank 0.12 foot thick, temperature about 50° , with the following results:

Length. l	Width. w	Head. $H = h$	Discharge, cu. ft. per sec.	C	c
1.0625	1	1	5.045	0.5922	0.5988

The coefficients C and c are used in the following formulas respectively: $Q = C (2gh)^{\frac{1}{2}} l w$ and $Q = c \frac{2}{3} l (2g)^{\frac{1}{2}} (H_b^{\frac{3}{2}} - H_t^{\frac{3}{2}})$. $H^b = h + w \div 2$ and $H_t = h - w \div 2$.

Following is given a table of the results obtained from the writer's experiments made at Bozeman, October, 1894;

DETERMINATION OF VALUE OF MONTANA STATUTE MINER'S INCH.
THICKNESS OF PLANK AT THE OPENING, 2 INCHES.

(2g) = 8.02. Temperature of water 40°-50° F. $Q = C (2gh)^{3/2} lw$, $h = H + h_a = 0.5$ foot.

Length in in.	Width in ft.	Number of Miner's ins.	Discharge in cubic feet per second.		Gallons per Miner's inch in 24 hours.	Percentage of increased flow per unit of area.	Head over center in feet. $h = H + h_a$
	w		Q	C			
6	1	36	0.8406	.593	15108		
8	1.2	48	1.13214	.599	15260	1.008	.5
10	1.3	60	1.4246	.603	15363	1.677	.5
12	1.4	72	1.72088	.607	15464	2.355	.5
14	1.5	84	2.0176	.61	15542	2.855	.5
16	1.6	96	2.31719	.613	15620	3.372	.5
18	1.7	108	2.6174	.6155	15681	3.79	.5
20	1.8	120	2.9168	.6173	15727	4.097	.5
22	1.9	132	3.2173	.619	15770	4.3825	.5
24	2.0	144	3.52115	.621	15823	4.7347	.5
26	2.1	156	3.8268	.623	15872	5.057	.5
28	2.2	168	4.1318	.6246	15913	5.317	.5
30	2.3	180	4.4404	.6265	15964	5.639	.5

The hook gauge indicated a head (H) = 0.5 foot in the orifice box when the readings on the weir gauge were taken, but the actual head in the orifice box was H + the head due to velocity of approach, taken as $h_a = 1.4 V^2 \div 2g$. The value of C was deduced for a head, $= H + h_a$; this value of C was then inserted in the formula $Q = C (2gh)^{3/2} lw$ when $h = 0.5$ foot and a value for Q found, which is the value given in the table.

CONCLUSIONS.

The statute apparently assumes that a person appropriating 180 miner's inches gets five times as much water as a person appropriating 36 miner's inches. As might be expected, our experiments show that this is not a true ratio. As a matter of fact, as will be seen from the table, the former gets about 5.64 per cent. more water per unit of area of orifice than the latter.

Your committee believes that fairer and more satisfactory results would follow if the standard of measurement were expressed in cubic feet per second *without reference to the method of measurement*. The probable result of this would be that weirs would rapidly displace all other devices where accuracy was desired.

The enclosed form of Act is submitted for the approval of the Society, and we recommend that the Legislature be asked to adopt it.

We have many experiments on the flow of water over weirs, and there is no trouble in obtaining results that can be relied upon as being correct within one per cent. The weir has a further advantage over orifices in effecting a saving of head in diverting water for measuring purposes. This, in some cases, is a matter of considerable importance.

Permanent records of fluctuating heads may be kept by using an automatic registering device of the Carpenter pattern. This I believe to be an important matter. If canal companies and joint owners would use weirs with recording registers, I believe that much of the prevailing friction between neighbors would be done away with. These registers can be purchased in Denver for about \$20.

In selecting a value to represent a miner's inch of water, your committee would suggest that, providing the law giving present appropriators a water-right expressed in miner's inches be repealed, if 2.5 cubic feet per second were considered an equivalent for 100 miner's inches, 5 cubic feet per second an equivalent for 200 miner's inches and so on, no injustice would be done anyone. We would then be able to do what is now almost impossible; namely, to collect fairly reliable data relating to the duty of water used for irrigation. As matters stand at present we are told by certain parties that they use so many inches of water so many times per season, in order to irrigate a given area of land. Ordinarily we do not know how much water that represents, and we have no means of finding out. If a weir with a registering device were used, a glance at the card would tell the whole story. It would also show whether the appropriator was getting more or less than his share.

The Experiment Stations would gladly furnish cards showing the flow over weirs for different depths. In fact, Prof. L. G. Carpenter, of the Colorado Station, at Fort Collins, has already done so, both for rectangular weirs and for the Cippoletti weir.

The latter weir has sides which are inclined from the vertical $\frac{1}{4}$ in 1. This form of weir was designed for the Villoresi Canal, projected in 1881 by the Province of Milan, Italy, by Cesar Cippoletti.

Cippoletti attempted to perfect a design for a weir which would measure the discharge with an error not to exceed $\frac{1}{2}$ per cent. and at the same time to retain the simple formula $Q = Clh(h)^{3/2}$. The value of C he determined to be a constant $= 3.33$. Cippoletti's weir has been in use for about ten years in Italy, and has given general satisfaction.

Messrs. Flinn and Dyer have published the results of their experiments on the Cippoletti weir in the *Transactions of the American Society of Civil Engineers*, July, 1894. These experimenters conclude that a properly constructed Cippoletti weir will give results correct within one

per cent. We believe that no better form of weir can be selected by irrigators. For the measurement of large bodies of water where the construction of a weir is impracticable, straight measuring flumes similar to those used by Mr. Mead, State Engineer for Wyoming, and Mr. Clemens Herschel's venturi meter, are suitable.

AN ACT

establishing a standard of measurement for water, defining the equivalent of a miner's inch and repealing Section 1262, Division 5, of the Compiled Statutes of the State of Montana and all conflicting laws.

Be it enacted by the Legislative Assembly of the State of Montana :

SEC. 1. Hereafter a cubic foot (7.48 gallons) of water per second of time shall be the legal standard for the measurement of water in this state.

SEC. 2. Where water-rights expressed in miner's inches have been granted, one hundred miner's inches shall be considered equivalent to a flow of two and one-half cubic feet (18.7 gallons) per second ; two hundred miner's inches shall be considered equivalent to a flow of five cubic feet (37.4 gallons) per second, and this proportion shall be observed in determining the equivalent flow represented by any number of miner's inches.

SEC. 3. Section 1262, Division 5, of the Compiled Statutes of the State of Montana, and any laws in conflict with this Act are hereby repealed.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Welcome !

In the JOURNAL for December, 1894, the Box had the pleasure of announcing the decision of the Western Society of Engineers to continue its membership in the Association of Engineering Societies.

With equal pleasure we now turn to welcome two societies just admitted to membership, the Denver Society of Civil Engineers and the Association of Engineers of Virginia, numbering respectively twenty-five and thirty-seven members.

Each society added to our roll increases the value of the JOURNAL, not only to the members of the societies participating, but to the profession at large, and thus tends to increase its circulation and importance.

The Box entertains no doubt that the co-operation of the societies in question will redound to their advantage as well as to that of the Association.

Our Societies and the Legislators.

In *The Library* for the current month we have referred to the work of our new member, the Association of Engineers of Virginia, in shaping legislation by securing the passage of a new building law by the city of Roanoke, Va., in accordance with a draft submitted by the Association.

As will be seen by the proceedings of the January meeting of the Association, printed in this number, that body has also interested itself in the matter of a law looking to the improvement of the roads of the State.

The Montana Society has similarly brought its pressure to bear upon the legislature of that State in behalf of laws respecting the regulation of water measurement, the duties and compensations of county surveyors, and the improvement of roads. Professor Ryon's report upon the measurement of water, with a copy of the proposed act, is printed in the present number, and under the proceedings of the society is given an account of its efforts in the other two directions named.

As we go to press we learn that the Legislature, which, it is significantly remarked, was "elected to elect United States Senators" has indefinitely postponed the consideration of all three of the bills submitted. The society, however, nothing daunted by this frosty reception of its efforts for the public good, proposes to keep up "a fight all along the line for the next three years."

The Federated Institution of Mining Engineers.

Co-operation among engineering societies is not confined to this side of the water. The institution whose name appears at the head of this article comprises now six

important societies having their headquarters mostly in the north of England and in Scotland. Founded in 1889, it began operations, like our own Association, with but four societies, but these four boasted a combined membership of about 1200. The six societies now federated show a total membership of over 2000.

The scheme of federation is in many respects quite different from that of our own Association. The several societies publish separately their own transactions, and the work of the institution is not confined, as in our case, to the publication of papers, but extends also to the holding of general meetings.

Mr. M. Walton Brown, secretary of the North of England Institute of Mining and Mechanical Engineers, with headquarters at Newcastle-upon-Tyne, is secretary also of the Federated Institution, and to him we are indebted for interesting information respecting its scope and work, as well as for a copy of a report upon Flameless Explosives by a committee of the North of England Institute. This report, of sixty-nine pages and one lithograph plate, is the result of an elaborate series of experiments with various explosives and appliances connected with shot-firing, made as nearly as possible under the conditions obtaining in a mine.

The experimental station is at Hebburn-upon-Tyne, and is supplied with natural gas derived from a blower in the workings of the Hebburn colliery, about 500 yards distant.

The labors of the committee resulted not only in the report before us, but in a formidable array of papers upon various subjects more or less intimately connected with the investigation, contributed by members of the committee and published in the Transactions of the Federated Institution of Mining Engineers.

Annual Report of the Chairman.

The attention of our readers is called to the Annual Report of the Chairman of the Board of Managers of the Association, printed, under the Proceedings, in this number of the JOURNAL.

The Chairman's review of the history of the Association will be of interest to all, and especially to the members of the newly admitted societies.

The report of progress for the year just past shows a very considerable increase in the volume of the JOURNAL, with corresponding increase in the receipts and expenditures.

Under Prospects for the Future, the Chairman discusses projects recently renewed, looking to the establishment of a more intimate union between the societies of the Association, projects which we shall hope to see more fully discussed in this department.

The Articles of Association.

In this number is presented also a copy of the Articles of Association, which constitute our fundamental law.

From time to time, amendments to these articles have been submitted to the societies by the Board of Managers, but these have uniformly failed of the necessary ratification, and the articles therefore remain to-day as they were adopted at the first meeting of representatives of the four original societies, held in Chicago, December 4, 1880.

Trolley English.

In the Contribution Box for February, 1894, under the heading, "As She is Printed," we gave the following, taken from the transfer ticket of a Philadelphia street-car line :

"This Transfer Ticket is given only to persons entering car on Pine Street, and asks for and receives same at time of payment of Cash Fare. Otherwise the Conductor is not permitted to give it."

A pocket-guide to the trolley and other street-cars of the same city, recently issued, contains the following caution :

"Owing to the starting of new lines, and change of schedules, the information below is as near correct as possible."

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

The Engineer and Contractor. Mr. Ernest McCullough, C. E., Member of the Technical Society of the Pacific Coast, whose treatise on Public Works we briefly noticed in the LIBRARY for December, appears as the managing editor of this new engineering weekly, whose first number appeared January 4, 1895.

It is an eight-page sheet devoted primarily to the interests of western engineers, and one of its principal aims is to present, for the benefit of engineering contractors, the latest information respecting construction work in that section. An illustrated paper on the diverting dam of the Peoria Canal Co., by Mr. H. Clay Kellogg, Member Tech. Soc. Pac. Coast, begins with the first number and runs into the fourth, where it is announced that "the next number will give a general idea of the manner in which the work is prosecuted, and some statement of cost." No. 5, however, brings the sad intelligence of the failure of this dam, with severe editorial strictures upon the manner in which the work was done, and particularly upon the policy of the management in dispensing with the services of the engineers before the dam was quite completed.

Mr. C. E. Grunsky, C. E., contributes a paper on Public Works in American Cities, read before the Political Science Club of the University of California, and Mr. Otto von Geldern, Secretary Tech. Soc. Pac. Coast, one on Macadamized Roadways.

It is to be hoped that the promise of this new journal that "in tone it will be quiet," will not be carried out too literally.

City Roads and Pavements suited to Oswego, New York. By William Pierson Judson, M. Am. Soc. C. E., M. Inst. C. E. Oswego, N. Y.: R. J. Oliphant, 1894. 60 pages.

While this work, as indicated in its title, is prepared with special reference to the needs of the city of Oswego, it is believed that it will find application in many other cities of this country.

Chapter I is devoted to the local conditions obtaining in Oswego; Chapter II to a brief discussion of the claims of different systems of paving; and Chapter III-VIII to a more detailed consideration of their several advantages and disadvantages.

The author reaches the conclusion that sheet asphalt, laid upon the old stone pavements as a foundation, is best suited for the main business streets of heaviest traffic; block sandstone upon a 6-inch concrete base, for the main business streets with grades steeper than 3 per cent.; vitrified brick upon a 6-inch base for semi-business streets and thoroughfares, and sheet asphalt for resident streets where there is much driving.

The work is very handsomely got up and is profusely illustrated with photographs and with colored lithographs of the different forms of construction. The inadvisability of using broken cobblestones for foundation is well illustrated in one of the latter.

City of Portland, Maine. Annual report of the City Engineer for the year 1893-1894. By Mr. George N. Fernald, City Engineer.

The extent to which the question of sanitation is engrossing the minds of the dwellers in cities is indicated by the fact that by far the larger part of this report is taken up with the discussion of matters pertaining to sewerage. Nearly a mile of sewers was constructed during the year covered by the report, and the city now has a total of more than 40 miles.

Theoretical Mechanics. AN ELEMENTARY TREATISE ON —. By Alexander Ziwet, Assistant Professor of Mathematics in the University of Michigan. Part III: Kinetics; 236 pages; 5½ x 9 inches. New York: McMillan & Co., and London, 1894. Price, \$2.25.

This is the third volume of the series, of which the first two parts, on Kinematics and on Statics, respectively, were noted in the September JOURNAL, and is altogether in keeping with them. The larger portion of the present volume is taken up by Chapters V and VI, treating respectively of the kinetics of a particle and the kinetics of a rigid body. The motion of a variable system is briefly treated in Chapter VII.

Genessee River Storage Project. FINAL REPORT ON —. By George W. Rafter, Engineer in Charge. Albany, 1894.

The prominent feature of this report is the account of tests of 174 12-inch concrete cubes, made chiefly with a view to determining the effect of the character of the stone and sand used in the concrete and the availability of American cements. The results are contained in an elaborate table, giving the final compressive stress, and that at which the first crack appeared, and in most cases the observed compression of the block.

From the results of his tests the author concludes that the strongest concretes are secured when the volume of the mortar is very little, if any, in excess of the voids, as measured before compacting, or even a little less.

The tests were made upon the great testing machine of the Phoenix Bridge Works, at Phoenixville, Pa.

Sewage Disposal. A DISCUSSION OF THE PREVAILING RULES AND PRACTICES RELATING TO —. By Wynkoop Kiersted, C.E., M. A. S. C. E. New York: John Wiley & Sons. 1894. 182 pages, 5 x 7 inches. Price \$1.25.

The extent to which the subject of sewage disposal is interesting the public mind may be gathered from the appearance, in rapid succession, of treatises upon the subject. In the JOURNAL for November, we noticed the works of Messrs. Waring and Rafter. We now have before us this little book by Mr. Kiersted, member of the Engineers' Club of Kansas City, whose paper upon Water Supplies appeared in the JOURNAL for January last.

Mr. Kiersted advocates what may be called the natural or vital purification of sewage, namely, that by dilution or by discharge into running streams, holding that if this is properly regulated as to amount and character, and if the water is afterward properly treated by filtration, no injury need be wrought thereby.

This method is therefore given the place of honor in the work, but the methods by irrigation, by intermittent filtration, and by chemical precipitation, are also discussed.

Curiously enough, the work is printed in short forms upon long pages, giving what appears to be an unnecessarily deep margin at the foot of each page.

Massachusetts State Board of Health. TWENTY-FIFTH ANNUAL REPORT OF —, FOR 1893. Boston, 1894.

The excellent work of this Board has made it world-famous, and its reports are looked upon as among the most valuable of contributions to the literature of sanitation. In addition to the matter usually treated of, the present report contains papers upon the amount and character of organic matter in soils, and its bearing upon the storage of water in reservoirs, by Thomas M. Drown, M.D., chemist of the Board; Experiments upon the Purification of Sewage and Water at the Lawrence Experiment Station during 1893, by George W. Fuller, Biologist in charge (143 pages); the Chemical Precipitation of Sewage at the World's Columbian Exposition, Chicago, 1893, by Allen Hazen, Chemist, Department of Water Supplies, Sewage and Fire Protection; and Isolation Hospitals for Infectious Diseases, by S. W. Abbott, M.D., Secretary of the Board. The last-named paper is illustrated by plans of the hospitals at Cambridge, Ealing, and London, England, Blegdam's Hospital, Copenhagen, and with designs for a small isolation hospital.

Mr. Ira F. Mills describes the filter-bed installed during the present year at Lawrence, Mass., as the result of the work of the Board in connection with the investigations made at its experiment station there. The bed, finished in September, 1893, covers an area of $2\frac{1}{2}$ acres, supplies water for about 47,000 persons, and cost about \$67,000. Very frequent examinations of the water show that 98 per cent. of all the bacteria in the river-water applied to the filter are removed directly by it, and that only one-half of 1 per cent, and those of varieties not known to be in any way injurious to health, finally reach the persons using the water. For the three months of October, November and December, the average deaths from typhoid fever in Lawrence, during the five years preceding 1893, averaged eighteen, while, in 1893, or after the introduction of the filter, only four deaths occurred from that disease during the same three months.

**Concrete Bridge over the Danube at Munderkingen. (Be-
tonbrücke über die Donau bei Munderkingen.) Stuttgart, 1894.**

This arch, with 164 feet (50 meters) span and 16.4 feet (5 meters) rise, spanning the Danube with one opening, is of concrete composed of one part Portland cement from the Ehingen-Blaubeuren works in Upper Swabia, two and one-half parts river sand and five parts river gravel, both of the latter from the Danube.

In order to render the structure statically determinate, and also to prevent injurious stresses under changes of temperature, the arch is jointed at the crown and at the springs. As the bridge is on a skew of 15 degrees, the twelve boxes constituting each joint are set one in advance of the next, across the width of the arch. After the completion of the arches, the joint-boxes were loosely filled with cement mortar, to prevent them from rusting. This, it is claimed, does not interfere with the distribution of the stresses.

On the left side of the arch the intrados is struck with a radius of 213 feet (65 meters); but that on the right is struck with a radius of 230 feet (70 meters) for two-thirds of the distance from the crown to the skewback, and with a radius of 151 feet (46 meters) for the rest of the distance.

The cross-section of the arch rib sustains a maximum pressure of about thirty-four tons per square foot.

The total average settlement of the crown was about $4\frac{3}{4}$ inches (116 mm.).

The Great Arched Bridges of the Royal State Railway Stanislaw - Woronienka. (Die Bauvollendung der grossen gewölbten Brücken der k. k. Staatsbahn Stanislaw-Woronienka.) By Ludwig Huss, Vienna. 1894. Pamphlet, 8 pages. Reprint from *Zeitschrift des Oesterr. Ingenieur- und Architekten-Vereins*, Nr. 46. 1894.

Of the two arches here mentioned, both of which span the River Pruth, in Galicia, that at Jaremeze has a span of 65 meters, or 213 feet, and is believed to exceed, in this respect, any other stone railway bridge in the world. The first train passed over these bridges October 26, 1894, and on the 11th of the following month they were tested with a load of three locomotives, which produced no deflection. The pamphlet is illustrated with photographic views of the bridges.

An Ordinance to Provide Regulations Covering the Erection of Buildings in the City of Roanoke, Va. Compiled by the Engineers' Association of Virginia. Approved June 23, 1894. Roanoke, Va. 1894. Pamphlet, 20 pages.

This pamphlet is a gratifying evidence of the esteem in which the advice of the Association in question is held by the municipalities of its State, and we trust it may be taken also as indicating a growing disposition on the part of our legislators to look to such organizations for advice in matters pertaining to their several spheres.

The ordinance provides that plans, specifications and statements of material shall be submitted to the City Engineer before construction is begun, and it is made the duty of that official to examine the condition of all buildings undergoing alterations or being erected within the city limits, and to serve notice upon contractors or builders, and upon owners or architects, of structures which he may deem unsafe.

The report wisely devotes a page or two to definitions of the terms employed. Diagrams are given showing prescribed thicknesses of walls, arrangements of plumbing and drainage, etc.

Le Canadian Pacific Railway. By MM. L. Périssé & A. V. Roy. Paris 10 Cité Rougemont. 1894. Reprint from *Mémoires de la Société des Ingénieurs Civils de France*.

The authors here give the result of a very careful study of the system under consideration, made during their visit to this country in 1893. The location, construction and operation of the road are described in considerable detail, and the paper is illustrated by two plates showing the plan and profile of the line, with illustrations of bridges and other structures, and of rolling stock.

Spannungs-Ermittelung und Stellung der Trägerquerschnitte für Biegemomente, welche nach Grösse und Richtung veränderlich sind. (Determination of the Stresses and Cross-Section of Beams subject to Bending Moments Varying in Amount and in Direction.) By Professor G. Barkhausen, of Hanover.—Reprint from *Centralblatt der Bauverwaltung*.

The author, finding the methods in use for the purpose here indicated more or less deficient in certain respects, proposes here a method which, he claims, requires no special preparation upon the part of the reader, which, under all circumstances, permits an exact solution of the problem in hand, and which facilitates a general view of the relations obtaining in the given case.

The process consists in drawing, in the cross-section for the danger points, lines

representing the stresses which would obtain if a bending moment = 1 gradually described an angle of 360° with reference to the cross-section.

The method is illustrated by two examples showing its application to purlins of double channel section and Z section respectively.

Masonry Dams, THE DESIGN OF — (Berechnung der Staumauern). Von Franz Kreuter, ord. Professor der Ingenieurwissenschaften an der Königl. Bayerischen Technischen Hochschule in München. Berlin: 1894. Wilhelm Ernst & Sohn. Pamphlet, 12 pages.

The author here elaborates his method for the design of masonry dams, as somewhat more briefly outlined in his paper published in the *Proceedings of the Institution of Civil Engineers*, Vol. CXV. The right-angled triangle with vertical back is taken as the simplest among those cross-sections which give uniform stability throughout, and the method consists in finding the necessary modifications for transforming this ideal section into one adapted to the conditions of practice.

The cross-section is divided horizontally into four parts, the uppermost of which is rectangular. The width of this portion is supposed to be determined by local conditions, and its height is made equal to the product of the width by the square root of the specific gravity of the masonry.

The portion next below is trapezoidal, with height equal to that of the top portion, and bottom width 1.7 times its top width, the latter being of course the same as the uniform width of the top portion.

The two remaining parts have curved profiles, and their equations are much less simple.

Society Proceedings.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA. *Proceedings of* —.

November, 1894. Vol. X, No. 9.

This number contains a paper of ten pages, by Mr. Daniel Ashworth, on *Losses in Boiler Practice and Some of their Causes*. The author claims that the losses in question are due less frequently to insufficient theoretical knowledge than to neglect of the obvious requirements of good, every-day practice in the boiler-room itself, a neglect evidenced by such defects as cracked furnace-walls, the fouling of tubes, the accumulation of scale, etc.

December, 1894. Vol. X, No. 10.

W^r. William A. Bole discusses *Losses in the Steam Engine*, arguing that about five-sixths of the heat required in producing steam are wasted in the exhaust. In the *Proceedings of the Chemical Section*, Mr. Francis C. Phillips describes *Some Uses of Hydrogen Peroxide in Analytical Chemistry*.

January, 1895. Vol. XI, No. 1.

This number comes to hand, not "as we go to press" but as we are nearly coming off. It contains the proceedings of the 15th annual meeting, held in Allegheny, Pa., January 17, 1895. President Davis, in his annual address, confines himself chiefly to the engineering interests of Pittsburg and its vicinity.

The Treasurer's report for the year ending January 17, 1895, shows an expenditure, for "printing and binding," of \$1,388.50. The total number of pages in the volume for the year, including papers, advertisements, blanks, cover, etc., was 352, making the cost, for a membership of about 450, \$3.94 per page.

Assuming that these figures include composition, corrections, paper, presswork, illustrations and binding, we find that, for the same items, the cost of the JOURNAL

OF THE ASSOCIATION OF ENGINEERING SOCIETIES, with an average aggregate membership, during 1894, of about 1200, was but \$3.26 per page, or more than one-sixth less, notwithstanding that our pages, of the form used for papers, etc., contain more than one-third more matter, to say nothing of a large number of small-type pages in the JOURNAL containing, of course, a quantity of matter much greater still and costing much more for composition.

The comparison merely illustrates the economy that may be effected by co-operation in this as in other matters.

ENGINEERS' CLUB OF PHILADELPHIA, January, 1895. Vol. XI, No. 5.

Dr. Henry Leffmann discusses the timely subject of the Filtration of Public Water Supplies; and Mr. George A. Bullock, Chief of the City Bureau of Highways, describes recent progress in Philadelphia in the matter of highway improvement. Mr. Frederick H. Lewis contributes a set of Specifications for Portland Cements and Cement Mortars, with a valuable paper discussing them; and Mr. John L. Gill, Jr., maker of the Gill safety tubular boiler, describes and illustrates the remarkable and disastrous explosion of a battery of thirty-six plain cylinder boilers at Shamokin, Pa., on October 11, 1894. Following the practice of the *Proceedings*, the pages and the photographic views of the wreck are headed with the legend "Gill—Boiler Explosions," giving the uninitiated the impression that the paper and the photographs refer to an explosion of Gill boilers, which, it is needless to say, was quite foreign to Mr. Gill's intention.

In the proceedings of the meeting of November 17th is reported the discussion upon the invitation extended to the Club to confer with this Association with a view to membership therein, a discussion which unfortunately resulted in the Club's declining the invitation.

JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION. Quarterly.
December, 1894. Vol. IX, No. 2. 70 pages.

This number contains, among other valuable papers, Notes on European Water Supplies, by Mr. Allen Hazen, read before the Boston Society of Civil Engineers, and one by Mr. George Bowers, City Engineer of Lowell, describing experiments with tube wells in that city, and based upon a discussion of the subject before the same society.

Mr. Wm. Paul Gerhard, C. E., discusses the Water Service and Fire Protection of Theatres. Mr. George F. Chase describes the Laying of a 16-inch Main across a Rocky Mill Stream and over a Dam. Mr. J. C. Whitney contributes a paper on the Care of a Water Meter, and Mr. R. C. P. Coggeshall, Secretary of the Association, describes a Portable Platform to Aid in Excavating Trenches. The number closes with the Association's valuable table of statistics for the year 1893, in which are embraced twenty-one New England towns and the cities of Troy and Yonkers, N. Y.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis;

and the

Boston Society of Civil Engineers
was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE
ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS
HEREUNTO SUBSCRIBING, HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and transactions of the participating societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each society shall decide, and shall hold office until their successors are chosen.

SEC 2. The officers of the Board shall be a chairman and secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transac-

tions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the chairman for countersignature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

SECTION 1. Each society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

SEC. 2. Each society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any society may be used as it shall see fit. Payments by each society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions, as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any society may withdraw from this Association at the end of any fiscal year by giving three months notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any society may, at the pleasure of the Board, be excluded from this Association, for non-payment of dues after thirty days notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several societies upon the following dates :

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following societies have since certified their acceptance of the Articles, and have become members of the Association of Engineering Societies :

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, Minn., December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

Annual Report of the Chairman of the Board of Managers.

ST. LOUIS, January 31, 1895.

To the Members of the Board of Managers of the Association of Engineering Societies.

GENTLEMEN :—In submitting to the Board of Managers, and to the members of the societies now belonging to the Association, my first annual report, I think it is desirable to present a short review of the history of the Association. More especially is this necessary since two new societies have recently joined the Association, and their members are unfamiliar with its past history.

I. HISTORICAL REVIEW, TO DECEMBER, 1893.

The Association of Engineering Societies was first proposed about May, 1880, by the Civil Engineers' Club of Cleveland, Ohio, Mr. A. M. Wellington, a member

of that club, being the principal leader in the movement. After some correspondence with various local societies, committees were appointed by the Boston Society of Civil Engineers; the Western Society of Engineers, of Chicago; the Engineers' Club of St. Louis, and the Civil Engineers' Club of Cleveland; and the committees of the three societies last named met for the first time on December 4, 1880, in Chicago, for the purpose of preparing articles of association. There were present, at this meeting, Messrs. Benetzette Williams and L. P. Morehouse from the Western Society; M. E. Ransom and A. M. Wellington of the Cleveland Club, and Professor Charles A. Smith of the St. Louis Club. The Boston committee was represented by letter only. Mr. John W. Weston, of the Western Society, was present by invitation. This committee prepared the present Articles of Association, which are reprinted in this number of the JOURNAL. These Articles were adopted by the Engineers' Club of St. Louis, on January 5, 1881; by the Civil Engineers' Club of Cleveland, on January 8, 1881; by the Boston Society of Civil Engineers, January 19, 1881, and by the Western Society of Engineers, on April 5, 1881. By this action, four local societies joined together for the purpose of sustaining a joint monthly publication of their proceedings.

The addresses issued by this committee at the time of the submission of the Articles of Association, so clearly define the objects then in view, and so clearly express the sentiments of the present chairman in regard to the future development of the Association, that he here transcribes a portion of that address as expressing also his own hopes and those which have commonly been held by the Board of Managers.

"The Association has been called into being by no narrow spirit. Many of its promoters believe that local engineering societies should be established and fostered in every center of population where the engineering profession is sufficiently strong to support one; thus bringing each member within the easiest possible reach of his society. They also believe that these local societies should be brought into affiliation by some association with a wider sphere of action, by means of which common purposes may be executed, and through which their energies may be stimulated to high professional aims.

"While many have been actuated by this broad spirit, the co-operation of these widely-separated societies has been, perhaps, mainly secured through a desire to effect an interchange of professional papers. To this desire the first number of the JOURNAL OF THE ASSOCIATION may be said to owe its origin.

"May we not hope that this act of co-operation is merely the initial stage in the development of an organization from which more than the interchange of papers will be realized, and for which we may reasonably predict a great future?

"We surely indulge the belief that the Articles of Association were not only begotten in a generous spirit, and are not only founded upon correct principles, but that they possess sufficient vitality and adaptability to permit growth in any direction which experience may indicate as desirable; that by wise counsel and the cultivation of a professional *esprit de corps*, an organization will ultimately be evolved from this beginning which will perform a work not now being done by any association in the land; a work beneficial to the participating societies as societies, and to every engineer who desires a better tone and higher standing for the engineering profession.

"In saying this we are not unmindful of the imperfections which are known to exist in the plan of organization, and of the probable existence of still other defects which are not now so apparent.

"We do not, however, believe these defects to be fatal. We think that any tendency endangering the prosperity or usefulness of the Association can be counteracted by the adoption of measures which come fully within the scope of action prescribed by the articles under which the Association exists.

"On behalf of the participating societies, the Board of Managers ask for the Association and its publication the earnest support of its friends, and the candid consideration of those to whom the wisdom of its creation has not as yet been made manifest.

"They also appeal to kindred societies for their co-operation, hoping thereby to establish a medium for the interchange of professional literature which will be enduring; and to create an Association which, by a unity of professional interests, will be perpetual in its benefits."

For many years no other local societies joined the Association. There was a time when it was difficult to secure a sufficient amount of matter to maintain the monthly publication in a creditable form. In the first volume of the *JOURNAL* the transactions and proceedings of each of the four societies were printed separately, with their individual society headings. This was done to satisfy a sort of local pride which these several societies had in seeing their matter placed distinct and apart from that coming from other societies. It made an awkward arrangement, however, to have the societies' proceedings scattered through the monthly numbers in this manner, and after the first volume the custom was abandoned, and the papers were printed in one portion and the proceedings in another portion of each monthly number without attempting to keep separate those of the several societies. It has always been customary, however, to indicate, at the beginning of each paper, the society before which it was read.

The following societies afterwards joined the Association:

The Engineers' Club of Minneapolis, July, 1884.

The Civil Engineers' Society of St. Paul, Minn., December, 1884.

The Engineers' Club of Kansas City, January, 1887.

The Montana Society of Civil Engineers, April, 1888.

The Wisconsin Polytechnic Society, June, 1892.

The society last named withdrew from the Association at the end of March, 1894, and since then eight societies have participated in the work of the Association.

When the Association was organized, the total membership of the four societies participating was less than 500.

Meetings of the Board have been held at irregular intervals. The following are the dates of all the meetings of the Board since the organization of the Association, with references to their records as printed in the *JOURNAL*:

First meeting, Cleveland, June 11, 1881. Vol. I, page 5.

Second meeting, New York, September, 4, 1884. Vol. III, page 329.

Third meeting, Chicago, April 15, 1887. Vol. VI, page 215.

Fourth meeting, Chicago, December 3 and 4, 1889. Vol. VIII, page 589.

Fifth meeting, Chicago, September 11, 1891. Vol. X, page 511.

Sixth meeting, Chicago, August 1, 2 and 3, 1893. Vol. XII, page 330.

While necessary expenses of the members of the Board, incurred especially for attendance on these meetings, have been paid from special assessments levied upon the participating societies, the meetings have usually been held at such places and times as to render these expenses as light as possible. During the past year the Board has transacted a considerable amount of business by correspondence, and while this is less satisfactory than the holding of meetings, it is also, of course,

very much less expensive, and it is usually found adequate to the transaction of routine business.

The business arrangement for the publication of the JOURNAL has varied from time to time. From November, 1881, to April, 1887, the JOURNAL was published by the Board of Managers, who were responsible for all bills incurred. During this time the JOURNAL was printed by Messrs. Atkin and Prout, of New York City, under a contract for composition, paper and presswork, and mailing, all bills being approved by the Chairman of the Board. During this time the Secretary of the Board was Col. H. G. Prout, a member of the firm named. From April, 1887, to April, 1890, the JOURNAL was published by the *Railroad Gazette*, under a standing contract, by which the Association paid the *Gazette* \$3.00 per annum for each copy of the JOURNAL sent to members of the participating societies, while the *Gazette* received all other sums realized, including the receipts from outside subscribers, from advertisements and from sales.

The *Gazette* further agreed to print, of each number, 50 per cent. more copies than were required to supply the mailing list. Of these extra copies, such as were not sold were to be turned over to the Board at the termination of the contract. This arrangement was made because Col. Prout had become editor of the *Railroad Gazette*, and could no longer act as Secretary of the Board. By this arrangement the work formerly done by the Secretary, at a salary of \$600 a year, was to be done by the *Railroad Gazette* without further compensation.

This arrangement for the publication of the JOURNAL proved satisfactory, and no controversy ever arose as to the quantity of matter published, or as to the character or amount of the illustrations accompanying the papers. At the meeting of the Board, held in December, 1889, the publication of the JOURNAL was let to Mr. John W. Weston, then editor of the *American Engineer*, Chicago, on a basis exactly similar to that of the contract with the *Railroad Gazette*, except that the annual assessment was made \$2.75 instead of \$3.00 per annum. This contract ran for nearly two years, or until the close of Volume X, in December, 1891. From that time on, the JOURNAL has been published by the Board, as at first, the Board paying all bills and employing a secretary at \$600 per annum.

On one or two occasions, the Board of Managers has prepared amendments to the Articles of Association, having in view the enlargement of the scope and province of the Association. Such amendments can become a part of the Articles of Association only on their formal adoption by a majority of the Societies composing it. In default of such action by the Societies, the Articles of Association remain as they were originally adopted, and they are so printed in the present number of the JOURNAL.

At the meeting of the Board of Managers held in Chicago, August, 1893, certain rules governing the action of the Board were adopted. In accordance with these, its officers can be elected by letter ballot, and without necessitating a meeting of the Board. The terms of office of the Chairman and of the Secretary were made two years, and the transaction of business by correspondence was recommended. These rules were published in Volume XII of the JOURNAL, page 381.

The propriety of the publication, by the Board, of the Index to Current Technical Literature has been called in question during the past year by some of the Societies, and not only the advisability of such publication, but also the authority of the Board to conduct it, has been challenged. The history of this department is as follows :

At the second meeting of the Board, held in New York, September 4 and 5,

1884, the present Chairman of the Board, being then the representative for the Engineers' Club of St. Louis, proposed to prepare the matter for such a department if the Board would consent to its publication. He was then engaged upon the preparation of an Index Rerum for his own use, and saw the desirability of making more accessible for ready reference the vast mass of journalistic, society and fragmentary engineering literature which was then coming before the profession. As an experiment, the Board agreed to publish this matter for one year, and the writer fulfilled his part of the contract and prepared the necessary notes, doing the work without compensation other than the receipt of the exchanges of the JOURNAL. The work of preparing the notes proved to be very onerous, and required a large amount of time, and at the end of the year the writer agreed to do the work for another year for the sum of \$175, in addition to the exchanges, these latter being rated by him at a cash value of \$25 per annum for permanent preservation. The experiment had proved a great success, so far as the readers of the JOURNAL were concerned, and many new subscribers had been obtained by reason of the publication of these notes. The Board therefore voted unanimously to continue this department and to pay the price named for preparing the notes. The writer did the work for the second year himself, receiving slight assistance from a few public-spirited engineers who sent him some notes which he would not otherwise have obtained. While he has repeatedly requested the Board to assist him in getting rid of this burden, no one has as yet been found who was willing to undertake the responsibility for the compensation which the Board has continued to make, namely, \$175 per annum and the exchanges. Since the second year, therefore, the undersigned has paid out, for such assistance in the preparation of these notes as he has been able to obtain, the full amount received from the Board for this department. Most of the work has still been done in his office, by himself and his immediate assistants, and this is the situation at the present time. At all the meetings of the Board held since the inauguration of this department, it has been unanimously voted to continue the publication of these notes at the rate named, and in the absence of other volunteers the writer has been requested to continue in charge of this department. The question of abandoning the department has, during the present year, been submitted by letter to the members of the Board, and but two votes have been registered against its continuance. This department partly pays for itself in the increased number of subscribers which it brings to the JOURNAL and in the better facilities which it affords for the display of advertisements. If an Index Department was needed ten years ago, much more is it needed to-day, and this demand has been recognized in various technical lines by the starting of other indexes of technical literature. That published by the *Engineering Magazine* is now very complete, but it lacks that which characterizes the Index published in this JOURNAL, namely, a note appended to each item, and prepared by a competent engineer, describing the scope, significance and value of the article indexed. Hence, while it is far more complete than the one published in the JOURNAL, it fails to give that information which enables one consulting it to decide whether or not it would be worth his while to consult or obtain a copy of the article. This is exactly the mental query which the Index notes in the JOURNAL are designed to answer. Furthermore, the Index published in the JOURNAL has the great advantage of an alphabetical arrangement, and of annual recompilation under a *single* alphabetical arrangement. While our notes make no pretense of being "complete," it is believed that they contain nearly all that is valuable in the line of *civil* engineering, and much in the lines of electrical and mechanical engineering, in the

English language, and some of that in the French and German. I believe the nearly unanimous opinion of the readers of the JOURNAL is that this department is well worth all it costs, and that its abandonment would be a misfortune. If the undersigned had not felt that this were true, he would long since have given up the work.

Some misapprehension appears to exist respecting the conditions under which the bound volume of the Index notes was published a few years ago. At that time the Index Department had been conducted for seven years, and seven annual index summaries had been issued. To consult these, one was obliged to look through seven different alphabetical lists, and it was thought that there was a sufficient demand to warrant the republication of these seven annual summaries in one new alphabetical arrangement, to be published in book-form, cloth bound. The then Chairman and Secretary of the Board, together with the undersigned, discussed the matter by correspondence, acting however, as members of the Board. It was decided that if as many as five hundred subscribers could be obtained for such a volume, at \$2.50 each, the Board could afford to proceed with the work. Circulars were therefore sent out, and after about three hundred and fifty subscribers had been secured, so much time had been lost that it was thought best not to wait any longer, for fear the matter, by age, would lose in value. At this time it was supposed that a considerable profit would result from such a publication, and this profit would have gone into the treasury of the Board. The Chairman and Secretary felt, therefore, that it was safe to order the compilation made, and the undersigned immediately set to work to prepare the matter. This proved to be a greater work than was anticipated, since it was found necessary to make an entire re-arrangement of the headings, and to supplement fully with cross-references. As there were over 11,000 of these notes, each of which had to be cut out and pasted on a separate card, and as all of them had then to be re-arranged, often with new headings written in and with all the necessary cross-references added, the work consumed considerable time, and was somewhat expensive. The cost of composition also was excessive, as three fonts of type were in continuous use, and high prices had to be paid for competent compositors. Furthermore, in order to sell the copies which had not been subscribed for, a large outlay became necessary in the way of printing, postage and clerk hire, in order to bring the volume to the attention of engineers. The undersigned took his pay entirely in published volumes, and succeeded in placing about one hundred and fifty copies, all told, amongst the members of the Engineers' Club of St. Louis. The other societies in the Association, having less personal interest in the work, took fewer copies. The result was that the receipts were considerably less than the total expense, and the volume has never yet paid for itself. Since it was a losing venture, the Board has never been asked to assume the responsibility of its publication, and the loss has fallen on the three gentlemen who undertook the work. A number of copies still remain in the hands of Mr. Weston, and these are sufficient to reimburse him, if sold, as, eventually, they doubtless will be. The Board, however, has had no responsibility in this matter, and has incurred no expense.

II. REVIEW OF THE WORK OF THE PAST YEAR.

At the meeting of the Board of Managers at Chicago in August, 1893, Mr. Benezette Williams, who had been Chairman of the Board from the beginning, declined a re-election to that position. In accordance with the new rules of the Board then adopted, the undersigned was subsequently elected Chairman by letter

ballot, and Mr. John C. Trautwine, Jr., of Philadelphia, was elected Secretary. These officers assumed charge of the publication of the *JOURNAL* with the January number of 1894. As they were elected for two years, their duties will continue for another year. While the duties of the Secretary necessarily involve a certain amount of editorial supervision of the matter published in the *JOURNAL*, his meagre salary does not warrant the Board in expecting him to spend very much time upon the work. It is, therefore, due to the present Secretary that the Chairman should here publicly recognize the benefits of his incessant labors in behalf of the *JOURNAL*, and express the sincere appreciation and grateful acknowledgment which those labors so justly deserve. He has in a marked manner devoted himself continually to the best interests of the *JOURNAL* in particular and of the Association in general, as he understood them, and has cheerfully and heartily responded to all requests and suggestions made to him by the Chairman and by other members of the Board. The benefits of his work are clearly seen in the *JOURNAL* itself. The editorial supervision of the matter printed in the *JOURNAL* has, I believe, been of a higher grade than any hitherto given to this publication, and the two new departments of the "Contribution Box" and "Library" have been mostly contributed by the Secretary.

The mailing lists of the *JOURNAL*, at the close of 1893 and of 1894 respectively, compared as follows:—

	Dec. 1893	Dec. 1894
Boston Society of Civil Engineers	325	353
Western Society of Engineers	354	337
Civil Engineers' Club of Cleveland	184	187
Engineers' Club of St. Louis	159	163
Civil Engineers' Society of St. Paul	28	34
Engineers' Club of Minneapolis	31	33
Engineers' Club of Kansas City	21	25
Montana Society of Civil Engineers	40	42
Wisconsin Polytechnic Society	42	
	<hr/> 1,184	<hr/> 1,174
Extra copies to members of Board of Managers, five each .	80	70
Advertisers	7	27
Exchanges	77	110
Subscribers and Complimentary copies	140	
Subscribers		176
Complimentary copies		15
	<hr/> 1,488	<hr/> 1,572

Besides this, many specimen copies have been sent out, with a view to increasing the circulation of the *JOURNAL* and securing advertisements; and authors of papers receive five copies of the *JOURNAL* containing them. As a rule, 2,000 copies of each number have been printed.

The *Journal* for 1893 (Vol. XII) contained

Papers	576	pages
Proceedings	82	"
Index, advertisement and blank pages	344	"
Covers	48	"
Title	8	"
Total	<hr/> 1,058	<hr/> "

The volume just closed (Vol. XIII, 1894) contains a total of 1,290 pages of printed matter, 86 cuts and 54 plates and full-page cuts, as follows :

	Papers.	Contri- bution Box.	Lib- rary.	Pro- ceed- ings.	Index & advertise- ments.	Total.	Number of cuts.	Plates and full-page cuts.
January . . .	58	4	2	20	24	108	8	5
February . . .	73	3	4	18	30	123	2	3
March . . .	45	4	3	14	26	92	8	1
April . . .	32	2	2	12	24	72	0	3
May . . .	42	4	2	8	24	80	11	2
June . . .	45	1	2	4	24	76	9	10
July . . .	68	3	5	2	24	102	2	13
August . . .	47	1	4	8	26	86	14	6
September . . .	79	2	3	6	26	116	9	3
October . . .	66	2	4	6	26	104	2	0
November . . .	57	1	6	8	24	96	10	6
December . . .	41	1	2	14	108	166	11	2
	653	28	39	120	386	1226	86	54
Covers . . .						48		
Index to volume . . .						16		
Total . . .						1290		

The number of pages exceeds, by 232, or about 22 per cent., that of Vol. XII, 1893, which was the largest that had appeared up to that time. In 1894 a larger type was used, but the size of the page was also increased, so that the page contains the same amount of matter as before.

Many of the illustrations are of a degree of excellence far beyond anything hitherto obtained in this publication.

At the close of 1893 the JOURNAL contained 7 advertisements, occupying 3 pages, and netting the Association about \$100 per annum. The number for December, 1894, contained 25 paid advertisements, occupying about 10 pages, and netting about \$850 per annum. In this respect the Association has received important aid from members of the Societies, notably the Boston Society of Civil Engineers.

In order to encourage the societies in obtaining advertisements for the JOURNAL, inducements have been offered from time to time in the way of sharing with such societies the profit from such advertisements. The rule of the Board now is, that 50 per cent. of the net income from all advertisements secured by any society in the Association shall be credited to the account of such society on the books of the Board, provided this credit be requested at the time the advertisements are obtained.

During the past year the Western Society of Engineers for a second time considered the propriety of withdrawing from the Association. As the Articles of Association require that notice of withdrawal shall be given three months previous to the end of the fiscal year, it was voted by the members, in meeting assembled to give such notice; but the question was then submitted to the full membership for decision by letter ballot. The movement in favor of withdrawal was due, not to dissatisfaction with the conduct of the JOURNAL, but to the impression that the best interests of the Society demanded this step preparatory to an anticipated career of wider influence as a national organization. The result of the letter ballot, however, was 137 to 70, or nearly two to one, in favor of remaining in the Association. This result is, of course, most gratifying to the members of the Board and to the other societies in the Association. So far as the Chairman is aware, no other society now in the Association contemplates withdrawing from it.

The Chairman takes great pleasure in announcing the fact that, as the result of a circular letter addressed, in October last, to the outstanding local and sectional societies, inviting them to become members of the Association, two other local engineering societies of high professional standing have recently joined the Association, namely, the Association of Engineers of Virginia, and the Denver Society of Civil Engineers. The total membership of these two societies is now about 60. The Technical Society of the Pacific Coast, with about 150 members, has voted to join the Association. The Engineering Association of the South has postponed for one year its decision as to joining the Association, but it is probable that at the end of that time it will apply for membership. Other local societies of good professional standing are considering the question of joining the Association, so that it is probable that within a year or two the number of societies co-operating will be materially increased.

III. FINANCIAL STATEMENT FOR THE PAST YEAR.

The following is a statement of the receipts and expenditures for the past year, as shown by the books of the Secretary:

CASH, 1894.

Dr.

To Assessments	\$3,636 00
" Subscriptions	298 00*
" Sales of JOURNALS	181 51
" Advertisements	760 50
" Sales of Reprints†	229 75
" Interest on Deposits	3 44
" Express charges refunded	2 92
	<hr/> \$5,112 12

Cr.

By Edward Stern & Co., printers	\$3,098 82
" Illustrations	636 00
" Secretary's Salary	600 00
" Commissions on Advertisements‡	89 50
" Discounts on subscriptions	17 20
" Traveling expenses	30 69
" Typewriting	24 00
" Mimeographing, etc.	50 30
" Freight from Chicago, hauling, unpacking etc., on back numbers of JOURNAL	118 84
" Stationery	33 83
" Messenger service	6 90
" Postage	55 43
" Notary's fees	1 50
" Copyright on January JOURNAL	50
" Telegrams	7 33
" Express charges	10 84
	<hr/> \$4,781 68

Cash Balance, January 1, 1895 330 44

* \$176.55 of 1894 subscriptions were collected by the former administration. See account below. The balance, so far as collected, and a few 1895 subscriptions, are included in the amount here given.

† About one-third of this item is profit to the Association.

‡ This item includes \$70.75 to the Civil Engineers' Club of Cleveland.

Mr. John W. Western, the former Secretary of the Association, renders the following account of his receipts and expenditures since the close of his account for 1893:

RECEIPTS.

From subscriptions	\$176 55
“ Engineers’ Club of Kansas City, on account of assessments	50 00
	<hr/> \$226 55

EXPENDITURES.

Postage, express charges and incidentals, transferring office	\$29 53
Secretary’s salary for January	50 00
Sorting, packing and shipping back files and materials, 45 cases	75 00
	<hr/> \$154 53
Balance	<hr/> \$72 02

Subject to the approval of the Board of Managers, I have accepted from Mr. Weston, in settlement of this account, fifty bound copies of Vol. I. of the Descriptive Index of Current Engineering Literature, reprinted from the JOURNAL OF THE ASSOCIATION, and covering the years from 1884 to 1891 inclusive. The selling price of these copies is \$2.50 each, or \$125.00 in all.

The cost of the various items of the JOURNAL for 1894 is given in the following table:

COST OF JOURNAL DURING 1894.

	1	2	3	4	5	6	7	8	9	10	11	12
	Printer.*	Illustrations.†	Index-Compilation.	Sum of 1, 2 and 3, ‡	Wrap-pers.	Postage on JOURNAL.	Mailing.	Secretary.	Sundries.‡	Total.	Number of Pages.¶	Cost per Page.
January	\$341 35	\$89 25	\$14 58	\$425 18	\$3 50	\$8 04	\$5 89	\$50 00	\$34 49	\$527 10	112	\$4 71
February	345 74	. . .	14 58	358 32	4 00	8 74	8 89	50 00	34 49	464 44	132	3 70
March	226 68	6 50	14 59	247 77	4 00	63 52	28 40 ¶	50 00	34 49	428 18	96	4 46
April	185 32	13 00	14 58	212 90	4 00	44 68	7 40	50 00	34 48	353 46	76	4 64
May	193 69	32 50	14 58	240 77	4 00	44 79	5 90	50 00	34 49	379 95	84	4 53
June	203 49	104 90	14 59	322 98	4 00	7 20	6 40	50 00	34 49	425 07	80	5 31
July	410 37	128 40	14 58	553 35	4 00	7 35	5 60	50 00	34 49	654 80	106	6 18
August	214 21	104 45	14 58	333 24	4 00	5 17	8 39	50 00	34 48	436 28	90	4 72
September	271 18	52 50	14 59	338 27	4 00	9 34	5 16	50 00	34 49	441 26	120	3 67
October	254 70	4 00	14 58	273 28	4 00	9 12	5 90	50 00	34 49	376 79	108	3 49
November	295 88	119 10	14 58	430 56	4 00	13 47	6 50	50 00	34 49	539 02	100	5 39
December	612 00	17 00	14 59	643 59	4 00	11 27	5 90	50 00	34 48	749 24	186	4 02
	\$3,553 61	\$651 60	\$175 00	\$4,380 21	\$17 50	\$292 70	\$100 33	\$600 00	\$413 85	\$5,774 59	1230	\$4 48

* The figures in Column 1 include composition, paper, presswork, binding and corrections.

† The figures in Column 2 include preparation of cuts, and paper and presswork on insets.

‡ The figures in Column 4 may be said to represent the cost of *manufacture* of the JOURNAL.

§ The figures in Column 9 include all expenditures of the Association (stationery, postage, circulars, etc.) chargeable to the JOURNAL and not otherwise noted.

¶ The figures in Column 11 include 4 cover pages in each number and 16 pages in index to volume.

‡ This includes \$22.50 for re-arranging, until list in alphabetical order.

The total cost of the JOURNAL for 1893 was \$4,517.78, or \$4.27 per page.

Owing to a ruling by the Post-Office Department to the effect that members receiving society publications in consideration of dues were not considered as *bona fide* subscribers, and that therefore such journals as our own were not entitled to second-class or "pound" rates (1 cent per pound), we were compelled to pay third-class rates (1 cent per 2 oz.) on the March, April and May numbers. See "Contribution Box," July, 1894, p. 397. This entailed an additional expense of about \$125. Deducting this, for purpose of comparison, we find the total cost of the JOURNAL for the year 1894, \$5,649.59, or \$4.38 per page.

In the report of expenditures for 1893, office expenses, postage and mailing are given in one amount. Estimating postage (at pound rates) and mailing for 1893 upon the basis of 1894, we have left, as office expenses, \$110.63, and find that the cost of publication proper compared as follows:—

	Total.	"Office Expenses."	Publication.	Pages.	Cost per page.
1893	\$4,517 78	\$110 63	\$4,407 15	1,058	\$4 16
1894	5,774 59	413 85	5,360 74	1,290	4 16

The increase in "office expenses" or "sundries," for 1894, is chiefly due to the inauguration of an active policy of advertising to the profession, by circulars, sample copies, correspondence, etc., the merits of the JOURNAL, with a view to increasing its advertising and subscription patronage and of securing the co-operation of outstanding societies. As will be seen from facts already stated, the increase in receipts from advertisements alone, already more than covers the entire office or sundries account, while, in addition to this, a considerable increase has been made in our subscription list, and new societies have been brought into the Association. It is believed, moreover, that the results of this policy, which is still being vigorously pursued, will continue to be felt, and in a greater degree, in the future.

The cost of the Index to Engineering Literature, for 1894, was approximately as follows:—

Compilation	\$175 00
Composition	
January to November, inclusive, 90 pages at \$2.75 . . .	\$247 50
December, 90 pages at \$2.75	247 50
	<hr/> 495 00
List of periodicals indexed.	
Composition, four pages at \$2.75	11 00
Charge for type standing, four pages, say	7 00
Paper, presswork and binding,	
11 months at 12 pages each 132 pages, say 8 forms, at \$17.00	136 00
December, 94 pages, say 6 forms at \$17.00	102 00
	<hr/> 238 00
	<hr/> \$926 00

With the present number an experiment is being made with the use of the linotype machine, in place of type-setting, for the composition of the index notes, and it is expected that, if the results of this prove satisfactory, a reduction of nearly fifty per cent. in the total cost of the index can be effected.

The Contribution Box and Library departments for 1894 contain, together, fifty-one pages, and their actual cost, for composition, presswork and binding, was about \$135.

It has been urged that the conduct of these two departments is beyond the province of the Association, the "primary object" of which, by our Articles, is defined to be the publication of the papers and proceedings of the participating societies; but it would seem to be within that province as viewed by the spirit of the Articles of Association, which empower the Board of Managers to publish in the JOURNAL excerpts from other journals, and, if the departments in question can be made to add to the value of the JOURNAL so as to increase its revenues and thereby aid in its publication, they are surely within the *letter* of the Articles.

It is much to be regretted that the members of the societies have not more generally acted upon the invitation, extended in each number of the JOURNAL, to send to the Secretary, for the Contribution Box, "such matters of general interest as may come to their notice."

As stated in the JOURNAL for January, 1895, it was hoped that the members would enable the Secretary to publish, in the Contribution Box, "those little matters, hardly of sufficient dignity or bulk to form the subject of a formal paper, which yet often rival, if they do not surpass, these more venerable documents in interest and utility." It is believed that if the members would contribute freely from their experience in this way they would greatly increase the value of the JOURNAL and its claims upon outside subscribers.

The following table shows the numbers of pages of papers contributed during 1894 by the several societies composing the Association, together with the number of members in each society at the close of October, the percentages which these form of the total membership, and the number of pages (or, to be more exact, the fraction of a page) contributed per member. For purposes of comparison, corresponding figures are given for the Engineers' Club of Philadelphia and for the Engineers' Society of Western Pennsylvania, two of the largest local and sectional societies still outstanding.

Society.	Number of Members, October, 1894.	Percentage of Total Membership.	Pages.	Pages per Member.
Boston	346	30.5	272	0.789
Chicago	297	26.2	152	0.512
Cleveland	184	16.2	70	0.380
St. Louis	173	15.3	83	0.480
St. Paul	32	2.8	24	0.750
Minneapolis	33	2.8	21	0.635
Kansas City	26	2.3	10	0.385
Montana	42	3.7	21	0.500
Association	<u>1,133</u>	<u>99.8</u>	<u>653</u>	<u>0.576</u>
Philadelphia	429	. .	199	0.465
Western Pennsylvania	455 *	. .	235	0.516

The question of making a special assessment on the Societies in the Association in order to balance the accounts of the year, was recently submitted to the members of the Board, and it was unanimously voted to make such an assessment. It is probable that no special assessment need be made, to cover the needs of the present year, and that by further increase of our subscription and advertising

* From list of members for 1894.

patronage, the cost of the JOURNAL to the Societies can hereafter be kept within the customary price of \$3.00 per annum per member.

IV. PROSPECTS FOR THE FUTURE.

The Board of Managers has often been requested to formulate some scheme by which the province of the Association may be enlarged and its work extended. It has been, for instance, proposed to hold an annual convention of the members of the participating societies, and that the union between these societies be made more vital. At present the joint publication of proceedings and transactions is all that these societies have in common. It is a serious question whether it is wise to make their union more intimate and vital. The societies in the Association are, in their nature and of necessity, local or sectional. They include in their several memberships technical practitioners of all kinds, and their peculiar province is to serve the purpose of bringing together in their several localities all persons professionally engaged in scientific and technical employments. For purposes of national organization these same individuals are organized along their several lines of practice, and there is little demand for national organization other than that afforded by the present national societies.

Beyond this evident advantage, it is doubtful if there exists any real need for organic reunion. Each local society should have its own independent autonomy, designed to serve the particular local interests of its own vicinity, and should be untrammelled by any higher or outside authority or influence. It seems to the undersigned, therefore, that these local societies are already reaping, in the joint publication which they now support, and which in turn materially aids in sustaining these local societies themselves, practically the full measure of the advantages of united action.

Respectfully submitted,

J. B. JOHNSON, *Chairman.*

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIV.

FEBRUARY, 1895.

No. 2

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

NOTES ON EUROPEAN WATER SUPPLIES.

BY ALLEN HAZEN, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read November 21, 1894.]

It has been my good fortune during the past year to visit a large number of the leading water works in central and western Europe, and I propose this evening, not to give you a systematic or exhaustive account of them, but simply to mention some of the points which have specially interested me, and which, I trust, may also prove of interest to you.

The question of securing an adequate supply of pure water is by no means confined to the western hemisphere, and the activity with which projects are being discussed and carried out in European capitals was a constant source of surprise to me, for we are apt to think of European cities as places of slower growth and more fixed habits, where public works would progress more slowly.

In London a royal commission has just been considering the question of the probable needs of the eleven millions of people which they estimate that London will contain in 1931.

Birmingham is just commencing the construction of an aqueduct which is to supply it with pure mountain water from Wales, and, on the continent, Brussels is considering the project for a water supply for the greater metropolis which it is proposed to form out of the city and its suburbs.

Hamburg last year completed the filters which had long been con-

templated, and the construction of which was hastened by the awful epidemic of cholera which ravaged the city in 1892. Berlin also is largely extending its works. In Vienna the supply of mountain spring water has recently been increased, and still other projects of much greater magnitude are being considered for the supply both of the central city and of the surrounding towns. Paris, which had so long suffered from the lack of an adequate quantity of water for domestic purposes, completed, in 1892 an additional spring water supply with a minimum yield of twenty-three million gallons, and still greater projects are now being discussed for execution as soon as the needs of the population exceed the present supply.

All of these schemes differ, in one striking respect, from corresponding projects in America. The quantity of water provided per head is always less than one half, and frequently not more than a quarter, of that considered necessary for American communities. The causes of this difference are not altogether clear. In some instances the smallness of the European consumption may, in a measure, be attributable to a smaller proportion of water-closets, or to the fact that the entire population is not provided with flowing water in private apartments. But, after making all possible allowance, there is still a wide discrepancy which cannot be accounted for by the greater comforts or cleanliness of the American cities. Fire protection in Europe is upon a radically different basis from that in America. In all European capitals the construction of other than fireproof buildings is strictly prohibited, and fires, as we understand them in America, can hardly be said to exist. In Berlin, during the past year, the quantity of water which supplied all the necessities of the fire department for extinguishing fires and other purposes was less than three thousand gallons daily, and in no other German city, except Hamburg, was so large a quantity required.

American water pipes are so planned throughout as to allow a concentration of water for fire purposes. European water pipes serve only for the distribution of water for domestic purposes, and there is no provision (or, if there be any, it is of a most rudimentary character) for concentration of the large volumes of water which would be necessary for extinguishing the fires which are of almost daily occurrence in American cities. This system permits the use of smaller pipes, and thus, no doubt, reduces the leakage from imperfect joints, and, at the same time, by greatly decreasing the cost, allows more attention to be given to the quality of the work.

Another element which, in Europe more than America, tends to restrict the use of water, is the use of meters. In German cities particularly, it is often the case that no water is sold except by meter; and in Berlin over 86 per cent. of all the water pumped is actually accounted

and paid for, leaving less than 14 per cent. for use for all public purposes, such as street sprinkling, public fountains, sewer flushing, etc., as well as for waste.

The study of the quality of water supplies has received a new impetus since the cholera epidemic of Hamburg two years ago. This epidemic, as you remember, caused, in less than a month, the death of eight thousand persons in Hamburg, while the neighboring cities of Altona, Harburg and Wandsbeck remained substantially free. The water supply of Hamburg at that time was drawn unfiltered from the river Elbe at a point slightly above the city, but where it was subjected to occasional pollution from Hamburg's own sewage, as well as to the constant but more remote pollution from the fifty cities, each with more than twenty thousand inhabitants, upon the watershed of the river and its tributaries, with an aggregate population of about six millions, not including the smaller towns or the country districts. The watershed of the Elbe, above Hamburg, has an area of about 52,000 square miles, and the annual rainfall is 28 inches.

The other cities mentioned had other and better supplies, and their escape from the cholera was attributed by the Imperial Board of Health, after a most thorough examination, to this fact. Since that time, Hamburg has pushed to completion, at a cost of \$2,300,000, the filters previously projected, and at the present time the city has one of the finest water supplies of Germany. The effect of this Hamburg-Altona incident was not confined to the local conditions. It has resulted in many radical changes throughout the German Empire. Two years ago Hamburg was the only city in Germany drinking unfiltered surface water, but there were a number of other cities, such as Stettin and Lubeck, which filtered their waters at high rates and under conditions other than those found most favorable where filtration has been most carefully considered. Probably as a result of its investigations at Hamburg and Altona, the Imperial Board of Health issued an order prohibiting the use of unfiltered surface water for drinking in any German city, and prescribing in those cases where filtration is employed the conditions under which such filtration should be executed. The order prescribed, for instance, the rate of filtration, the minimum depth of the filtering medium, the treatment of filters at the times of cleaning, and also suggested that the effluent from each single filter should be daily examined bacterially by some officer appointed by the city, and, if possible, permanently connected with the water works. Some of these rules were objected to by the water works engineers on the ground that they could not be carried out without too serious disturbance of existing arrangements. Afterwards a conference was arranged between the Board of Health and a committee selected by a permanent society

of water works engineers (Deutscher Verein von Gas- und Wasserfachmännern) and a new set of rules, differing somewhat in detail from the first ones, was prepared. These rules have since been issued by the Minister of the Interior, and they are binding upon all German water works. In accordance with them those water works which had filters incapable of conforming to the requirements, have, in every case, so far as I know, during the past year, reconstructed their works in a more or less thorough manner to meet the requirements, and the bacterial examination of water commenced in most cases on the first of April, 1894. In this connection I may say that the laboratory for the examination of water in connection with the Hamburg works is one of the best equipped which I have ever seen. It is placed in a separate two-story brick building, which contains rooms for the various departments, and every facility for conducting the large number of tests which the rules require.

Berlin also draws its water from rivers, and filters it. The populations upon the Havel and the Spree are less than that upon the Elbe, but the watersheds are also less, so that the pollution in proportion to the volume of water is not inconsiderable.

The filtration at Berlin is effected by some thirty acres of filters which have been vaulted over as a protection from winter weather. Formerly open filters were used, and much difficulty was experienced on account of ice; in 1889, during an unusually cold period, the filters became so far unserviceable, and the water supply deteriorated to such an extent, that the city suffered from a considerable epidemic of typhoid fever. Since that time the use of open filters has been abandoned as fast as new covered filters could be substituted for them.

Among the thirty German cities which either have more than one hundred thousand inhabitants, or supply water to that number of persons, there are eleven which supply filtered water, the raw water being in almost every case drawn from rivers. The other nineteen cities are all supplied with ground water, but the aggregate population so supplied is somewhat less than the population in the eleven cities supplied with filtered water. The supply of ground water in the volumes required by large cities, has received a great deal of attention in Germany. Dresden, with 300,000 inhabitants, is supplied from a filter gallery 4,900 feet long and 26 inches in diameter, extending along the Elbe about 70 feet from the river and about 10 feet below low water. The walls of this gallery are built with perforations, and are surrounded with coarse gravel and the natural material of the river bank. This gallery has been in use since 1875, and has always given an abundant supply of entirely satisfactory water. The level of the water in the gallery is reduced by pumping only to about 5 feet below the river, and

at the time of my visit there were nearly 12 feet of water in the pump well. These works were built by Engineer Salbach, and it is his idea that the six or eight million gallons of water drawn come entirely from the land side, and that only insignificant quantities, if any, of the river water find their way to the pumps. It is his idea that there is an extensive bed of gravel all along the river for miles, reaching up into Bohemia, and that in this gravel there is another river flowing beside the Elbe with lower velocity but vastly larger cross-section, and that it is the water of this underground river which he obtains. It is on this account that the projected extension of the Dresden works is placed on the other side of the river, and some miles away, in order to tap another portion of this subterranean river, as he feared that any extension in the present location would tend to unduly lower the ground water level and to cause infiltration of water from the river. Some miles above Dresden the Elbe flows between rock walls, and, so far as one can judge, over a rock bed, through the so-called Saxon Switzerland. It was my first thought that these rocks would act as an obstruction to Herr Salbach's underground river, and that the river, if such existed, must have its origin below this point, but Herr Salbach informs me that the stone at this point is mainly porous sandstone, and is capable of allowing the passage of water, and, in addition, there may be fissures. It seems to me, however, that similar objections might rightly be raised to the theory that similar underground rivers are flowing parallel to many New England streams.

The newer ground-water supplies have substituted separated wells with suction tubes for the galleries, a substitution which, it is said, greatly cheapens their construction for a given result. Leipzig, with 360,000 inhabitants, is supplied by such a series of wells located some thirteen miles from the city. The water is taken from gravel beds which probably mark an old course of the Mulde and which still carry large volumes of water having their origin in that river, and so far as they are not diverted for water supply, reverting to it lower down. This is a particularly interesting case, for the surface water from this neighborhood, what little there is, does not go into the Mulde at all, but flows in the other direction into the Saale. At this point the Mulde makes a little detour, and the Saale's watershed goes almost to its banks. The old Mulde channel thus lies, for a considerable distance, in the present Saale watershed. The country all about, as far as the eye can reach, is perfectly flat, except in a few places where ledges crop out. The surface shows a slope of about one in a thousand. The watershed of the little brook passing the works is quite insignificant and bears no relation to the supply, and there is no large body of water above the surface for miles. This old river bed is about three miles wide, and the gravel in

it is from 50 to 70 feet deep. The wells constructed by the city reach in a straight line nearly across the entire width of this gravel. The first wells, 140 in number, covered about one third the distance; afterwards 90 additional wells, 33 feet apart, were put down, and the latest addition which I saw in course of construction consists of 94 wells 60 feet apart.

The method of digging these wells is to put a 12-inch cast-iron pipe down to the depth required, digging out the sand from the centre as the pipe sinks; afterwards the permanent 7-inch pipe with a strainer about 16 feet long, is introduced, and inside of that an independent copper suction pipe reaching nearly to the bottom. In addition, a three-quarter-inch pipe is provided for taking samples and ascertaining the water level. When all is in position, the 12-inch pipe first put down is drawn up. Water is now pumped from the well by an electric pump, operated from a trolley running the length of the extension. With rapid pumping much sand is at first drawn until the particles which cannot pass the rather coarse sieve form a gravel layer around that point and hold back the sand without further trouble. By rapidly pumping on four wells at a time by means of the electric pumps the ground-water level is lowered far enough below the surface to allow the permanent collecting pipes to be placed. For this collecting pipe rubber connections are everywhere used instead of lead. They are said to be cheaper and tighter, and they can be taken apart at any time without the slightest damage to the pipe. They have also the advantage of greater flexibility. On a 2-foot pipe, a rubber ring, like a bicycle tire, but solid, and one-half as large again as the opening between the bell and spiggot, and of the exact diameter of the pipe, is placed on the end of the spiggot and is rolled into the bell, enclosing and flattening the rubber ring. The joint so made is air-tight for vacuum, and will hold at least four atmospheres of pressure without leaking. The joint is made complete in two minutes under water if necessary, and, so far as known, it does not deteriorate with time. It can be taken apart and readjusted as often as desired. On the regular distributing pipes in the city, lead joints are ordinarily used, but I was told that on bridges, where flexibility was desired, rubber had been used with entirely satisfactory results. The collecting pipe from these wells discharges into the pump well, which is lower than the point to which it is proposed to lower the ground water, and any air which may accumulate in the pipes is removed from time to time by an air pump connected with the highest points on the pipes. When properly arranged in this way, syphons can be used with lifts up to twenty-six feet. The water obtained in this way is of satisfactory quality in every way except that it contains a little iron. The first two series of wells were so built that each well could be

separately tested for iron, and the worst wells were shut off. This arrangement has not, however, been entirely satisfactory, and this year no provision is made for shutting off single wells. It is found that in passing through the thirteen miles of pipe and conduit (about one-half of each) to the distributing reservoir and over the measuring weirs, the water becomes thoroughly aerated and the iron is precipitated. Filters have just been constructed through which this water will in future be passed at an extremely high rate, and it is believed that no further difficulty with iron will be experienced.

A record is kept of the height of water in the different wells, and also of that in other wells in the vicinity. Pumping for years from the first section has not in the least lowered the water level in the other sections; and the flow of ground water, while slower below the wells, still continues in the same direction, showing that even now the wells do not intercept all the water there. The entire capacity of the plant is now estimated at 16,000,000 gallons daily. The old works, without the last addition, have yielded as much as 11,000,000 gallons.

Herr Thiem, consulting engineer for the Leipzig and other works, has an interesting method of estimating the capacity of a ground water supply. He sinks three wells equidistant from each other in the form of an equilateral triangle. No water is pumped from them at first, but the water level is observed carefully for some days. From these observations he calculates the direction of the slope, and consequently of the flow, of the ground water, as follows: He calculates the point, on a straight line joining the wells having the highest and lowest water levels, where the water level is the same as it is in the third well. Joining this point with the third well gives a line at right angles to the line of flow. A fourth well is now sunk in exactly this direction, that is, the line of flow, from one of the first wells, and the higher well is dosed with a quantity of salt solution, followed by enough water to force the salt into the surrounding gravel. Samples of water are now taken at intervals from the lower well, and analyses show when the salt passes. From this is calculated the velocity of the ground water, and, in connection with the cross-section of the gravel, the quantity of water passing is estimated, and this is regarded as the capacity of the source, making allowance for variation of flow at different seasons. Herr Thiem has no confidence in pumping tests of wells short of years of continued use.

At Charlottenburg, a suburb of Berlin, a ground water is used which contains even more iron than that at Leipzig. In this case there is no flow through a conduit to oxidize the iron, and instead the water is taken through coke towers at a rate of 100,000,000 gallons per acre daily. The water, in passing through the coke, is everywhere in contact

with air, and it is found that the water so treated can be passed through an ordinary sand filter at a rate of 25,000,000 gallons per acre daily, yielding an effluent entirely free from iron. The capacity of this plant is 13,000,000 gallons daily. This process, which has been perfected by Engineer Piefke, is also applied to a number of smaller supplies, and for removing the iron from the well waters used by a number of breweries in Berlin and in Breslau.

Munich has a ground-water supply which is collected in still another way. The original supply was a series of springs along the side of a ravine in cultivated, wooded and rather elevated land, just where the foot-hills of the Alps commence. The soil on the country back of this ravine undoubtedly furnishes the water, and is generally pervious, consisting chiefly of gravel, with more or less clay in places and a layer of slate below. The country is comparatively level, but is cut by the ravine of a river, 150 to 200 feet deep, which goes some distance below the intercepting layer of slate into the gravel below. Along one side of this valley and above the clay were natural springs, which were first taken for Munich's supply, but it was found that the bulk of the water discharged through crevices in the slate below the surface into the river, and extensive galleries above the clay were built to intercept it. The bottoms of these galleries are of concrete, and their roofs are stone arches 5 to 6 feet high. A perforated tile pipe, 18 to 24 inches in diameter, is laid directly under the gallery and communicates with it at intervals. Under ordinary circumstances all of the water flows in the lower pipe, but when the flow exceeds its capacity the surplus flows through the gallery above. In a few cases the drain pipe was omitted altogether. Except near the outlet, the stone arch over the gallery is laid without mortar, and is surrounded by gravel to allow the free admission of water. The whole is sunk in a clay to a depth of about 3 feet, but varying with the irregularities in the surface of the clay.

There are at present about 7,800 lineal feet of these galleries in use, and of these 4,800 feet are walled without mortar, but the remaining 3,000 feet are also supposed to collect considerable water. These galleries must be from 100 to 150 feet below the surface. In March, 1887, the lowest yield from them was 15,000,000 gallons per day, and almost as low a figure was obtained in October, 1893, both times for a few days only. In wet seasons the springs have yielded as much as 32,000,000 gallons daily for short periods, and the average quantity used by the city is about 12,000,000 gallons per day. The flow of the springs is always free, and so much of the water as is required is sent to the city, the rest being wasted into the river. The capacity of the aqueduct is 23,000,000 gallons per day. The length of the conduit to the reservoir is nineteen

miles, and the average grade is 1:880. The conduit, for the most part, is $4\frac{1}{2}$ by $2\frac{1}{2}$ feet in cross-section. It is seven miles from the distributing reservoir to the town, so that the entire distance is about twenty-six miles. The cost of the works was \$2,100,000.

Among the world's great capitals, Vienna has a unique supply. Its source is in the high mountains near the line of the Semmering railroad, about sixty miles from the city. The mountains are of dolomite, with streaks of pure limestone, all of tertiary origin. Under the whole is a continuous impervious layer of slate, just above which the springs are located. The bulk of the stone is solid, but there are many fissures through which the water flows. The surface of the stone has become disintegrated in places, and, where the slopes are not too steep, it is covered with trees. Otherwise there are bold rock cliffs, which give a most romantic aspect to the valley. The material is apparently rather pervious, for, excepting the water which flows from the springs, there is little evidence of flowing water upon the mountains, although the rainfall is rather heavy, averaging about 59 inches both on the summits and in the valleys. The tops of the mountains are nearly seven thousand feet high, and they have patches of perpetual snow, which, although they do not make much show from below, are of such extent that by melting in summer they swell the volume of the springs at the base of the mountains to from two to four times their winter flow.

The springs apparently have in places a tolerably direct communication with the surface, for a heavy rainfall will increase their flow in from six hours to two days, but the water never presents the slightest turbidity. Its temperature is constant for the whole year at 41° to 44° . The temperature of each spring is entirely constant, but all the springs are not exactly the same. As the mountains are entirely uninhabited, there is no reason to fear the introduction of incompletely purified rain-water. Ordinary rains do not affect the flows. The Kaiserbrunnen, as the largest of the springs is called, was brought to Vienna in 1873 through an aqueduct fifty-five miles long, and having a capacity of 40,000,000 gallons per day. This spring furnished an abundant water supply during the warm months of the year, but was inadequate to meet the growing demand in the winter months, when all the precipitation upon the mountains was in the solid form, and when there were no thaws to increase the flow of the springs. To aid the supply, a series of wells were put down ten years ago upon the line of the aqueduct in the valley of a river which it was thought would add a considerable quantity of water in winter at a time when it was most needed. The supply from this source, however, has been rather disappointing, not exceeding 3,000,000 gallons daily. In the past year other and more distant springs have been connected. The supply at the time of my

visit, July, 1894, 21,000,000 gallons daily, was drawn mainly from the Kaiserbrunnen and from another spring near by, while the water from the higher springs, at least 46,000,000 gallons daily, was all going to waste. The new springs will be required in the winter only when the Kaiserbrunnen is low. The minimum winter yield of the present wells is about 19,000,000 gallons per day. The population of Vienna is 1,500,000; about one half million, however, reside in the recently annexed suburbs, and are not as yet supplied with Vienna water. It is desired to so supply them as soon as a sufficient winter supply can be obtained.

Two projects are under consideration. One of these, which is being investigated by Herr Salbach, contemplates a series of wells in the valley of the Danube in the immediate neighborhood of the city, while Engineer Kinzer, who has constructed the recent additions to the present works, is working upon another spring water project of the same general nature, but drawing from even higher mountains about fifteen miles away in the direction of the Alps. He thinks that the cost of an additional supply of 40,000,000 gallons daily will probably reach \$20,000,000. Further supplies could be got from the neighborhood of the present works, but the mill damages are too heavy, and, in addition, it would be necessary to construct a new conduit. The city paid \$1,600,000 for mill damages alone on the last addition of 10,000,000 gallons to its supply. The site contemplated in Herr Kinzer's new project is upon government lands and there are no mill privileges. The aqueduct from the Kaiserbrunnen to Vienna has a grade of over ten feet in a mile, and the section above the Kaiserbrunnen for the recent additions has a fall of 1,100 feet in ten miles. The upper part of this is constructed of iron, and the arrangements are very different from those of the conduit built by Mr. Herschel a few years ago for the East Jersey Water Co. The distance is divided into sections, each having a fall of about 100 feet. At the end of each of these sections is a gate-house, and the flow of water through the section is throttled by a gate at the lower end of the pipe, the gate being so regulated as to keep the pipe always full of water. This necessitates the use of very much heavier pipe, as well as the construction of numerous gate-houses which are entirely avoided by Mr. Herschel's design. I was told that it was feared that if the water was allowed to flow freely the upper part of the pipe would be occupied by air, and that the pipe would become corroded and weakened.

Some miles of the conduit lower down were cut out of the solid rock, and, as one rides up the excellent road, which was itself built as an adjunct to the conduit, the only signs of the conduit are the frequent holes in the limestone crags, through which the rock removed was

brought out and dumped into the valley below. The size of these dumps affords the best indication of the magnitude of the enterprise.

Paris has long been supplied, for domestic purposes, with water from springs in several valleys at a great distance from the city. Until about two years ago, the available supply from these sources did not exceed 37,000,000 gallons daily, a quantity which was found inadequate for the two and a half millions of people dependent upon it. For street-washing, for manufacturing and other purposes, the city has an additional supply of water taken unfiltered from the Seine and from a canal, but this water is not ordinarily allowed to be used in the houses. Paris washes its streets instead of sweeping them, and the quantity of water employed for other than domestic purposes is very large, exceeding 80,000,000 gallons daily. For years it was the practice, when the quantity of spring water was inadequate to meet domestic requirements, to supply river water to the wards of the city in regular rotation. Before this was done, however, the inhabitants of the wards were warned of what was coming, and were advised to refrain from using the water for drinking. This condition of affairs was ended in 1892 by the completion of a new aqueduct from springs in the valley of the Avre supplying a maximum of 32,000,000 daily. For twelve miles the aqueduct has a diameter of $5\frac{1}{2}$ feet, and a fall of one in 2,500; for forty-six miles it has a diameter of 6 feet and a fall of one in 3,300; and in addition there are five miles of syphons where two lines of 40-inch pipe are used having a fall of one in 800. The total length of this aqueduct is sixty-three miles and the total fall 132 feet. The walls are 8 inches thick and are built of the natural stone of the country laid in Portland cement. The city is allowed by law to take a quantity of water not exceeding 30,000,000 gallons daily, and an ingenious device at the head of the aqueduct is employed to prevent more than this from being used. The water flows through a submerged orifice at a determined distance below a very long overflow weir, and as soon as the quantity of water reaches the legal limit the excess commences to flow over the weir and back into the river. Below this point and connecting with the aqueduct there is another spring which yields an additional 2,000,000 gallons. The springs supplying the water are scattered through the valley for about two miles above the head of the aqueduct, and are connected with three and a half miles of conduit. They are only a short distance below the surface. The springs, ten in number, were natural springs which formerly discharged over the surface into the river. They have been enlarged, cleaned and deepened, and covered in; the bottoms are made of coarse pieces of flint. The houses covering the springs are 15 to 40 feet in diameter. There are no other springs in the valley. Since the spring water has been collected,

the river bed has been dry and poplar trees are dying for the lack of water. The surrounding country, through which the water probably comes, is rolling and somewhat clayey, the clay containing large quantities of flint. The rock is chalk mixed with flint, while in the valley of the river there is gravel mixed with fragments of flint, all of which is rather porous. The springs are in this gravel, but I could not ascertain its extent. Judging from the topographical map, they may drain the country for fifteen miles back. It is all cultivated land and is occupied by an ordinary farming population. There is no manufacturing. The maximum flow of the springs is about 50 per cent. greater than the minimum, which comes in September. Nearly all of the water comes into the ten springs themselves, but in two or three places the collecting mains going over the minor springs are arranged to allow the entrance of water. Otherwise the mains are water-tight, and the drains built below them to aid in construction are discharged into the river. The aqueduct and the work at the springs cost in all four million dollars. The damage suits for water power and loss of water for irrigation are still pending, but I was told that it was expected that they would probably be settled for about three million dollars, making a total cost of seven millions. One hundred thousand dollars were paid for the springs themselves and the surrounding land. The present minimum of spring water at Paris from all the existing sources is about 53,000,000 gallons daily. This is the only water now taken into private houses. Only a part of the houses have water-closets, but their use is increasing, and thus more water will be required. The present sources are incapable of further development. For the future there are two projects, one for a grand system of filtration of river water; the other for a supply of spring water from the mountains in Haute Marne, 180 miles east of Paris. Studies for these supplies are about to be undertaken; the intention being to secure an additional 67,000,000 gallons daily. The present supplies will prevent the necessity of using unfiltered river water for at least ten years. The suburbs of Paris are all supplied by a private company which is just building an extensive filter plant, and it is proposed to use this in connection with the Anderson Revolving Purifier Process, taking the raw water from the Seine above Paris.

Some of the Dutch cities have a particularly interesting system of collecting water. A large part of Holland consists of land as low as, or lower than, the ocean, and the highest land in the country is a row of dunes, only a few miles wide, extending along the coast from Amsterdam to the Hook of Holland. These dunes consist of fine sand, and the level of the ground is from ten to twenty feet above the ocean. The dunes are entirely uninhabited. The water is collected from this area by a system of open canals. The water in the canals supports a growth of

algæ, and thus becomes unsuitable for use in its raw state. It is therefore filtered.

At Amsterdam about 6,200 acres of dunes are drained by 15 miles of open canals located below the ground water line. The yield of the land is equal to 14 inches of rainfall on the entire area, and the total fall is 28 inches. The entire summer rainfall is believed to be evaporated, and thus lost for water supply, but the bulk of the winter precipitation is utilized. The water, as it comes from the ground in canals, contains iron, but this is all removed by natural processes before the water reaches the filters. During the past year the average supply of water from these sources was six and a half million gallons per day, with a maximum of eight million gallons. Some years ago this supply became inadequate to meet the growing demands of the city, and the water company built, on the other side of the city, another plant, which takes its water from a canal or river not subject to excessive pollution, and the water is carefully filtered. These works, built at a cost of three million dollars, were intended to supply eleven million gallons daily, but the city authorities who wished to secure control of the water works, decided that this water did not meet the sanitary requirements, and that it could not be used for domestic purposes. It is, therefore, at the present time used only for street sprinkling and for other public and manufacturing purposes, about four to five million gallons daily being required. The city insists that the company must provide an additional supply of dune water, the estimated cost of which will be two and a half million dollars, and at the same time declines to authorize the company to increase its capital stock. The object is evidently to put the company in as unfavorable a position as possible, in order that the city may acquire the plant on favorable terms. The supplies of Leyden and of the Hague are of the same general nature as the dune supply of Amsterdam. It has been suggested that if covered collectors were used instead of open canals for collecting the water, filtration could be omitted and an equally good water could be supplied. On the other hand, it is said that covered collectors become rapidly choked by the extremely fine sand which there exists, and require from time to time to be dug up at great expense. It is also claimed that the water, if so collected, would contain iron, and would require treatment which might be as expensive as the present filtration. For the filtration of this dune water the dune sand itself is used. This is much finer than is elsewhere used for filtration. Its use here is rendered possible by the comparative purity of the raw water.

Brussels, with its two hundred thousand inhabitants, is supplied by ground water drawn from some five miles of collecting conduits in fine sand underneath the forest which also serves as a city park. The drains are generally from 100 to 150 feet below the surface. The possibilities

of the supply from this area are apparently nearly reached. Brussels is desirous of annexing her suburbs and of forming a greater Brussels, with a population of about half a million, and in case this is done an additional water supply must be procured. The city engineers are talking of an extension along the present lines but in new areas, and there is also a project for a supply of filtered water from the river.

The Continental cities are almost invariably supplied with either ground water or filtered river water. The use of impounding reservoirs is practically unknown. Chemnitz and Königsberg have very small reservoirs as auxiliaries to other means of supply, but it is only in England that we find great dams, similar to those so commonly used in America, retaining large volumes of water. Liverpool already derives its water supply from such a source in the Welsh mountains, and Manchester, Bradford and other towns in the north have similar supplies.

Birmingham is just commencing the construction, at an enormous expense, of an aqueduct to Wales, sixty miles away, and there has been talk of a similar supply for London, but in the latter case a royal commission appointed to consider the subject has decided that the present sources can be utilized for many years to come without bad results and at a less expense.

The waters from impounding reservoirs in England are generally filtered, although the watersheds are entirely free from pollution. In this way all trouble from bad tastes and odors due to algæ as well as from temporary turbidity during storms is avoided, and the results are believed to be commensurate with the cost of filtering the water. There are, however, a number of towns, including Manchester, which supply such water without filtration, and Glasgow draws its water from Loch Kathrine without filtration. In Germany, reservoir water is required by law to be filtered whether it is subject to pollution or not.

The following table contains a list of some of the principal European cities, with their populations, the quantities of water supplied daily, in millions of American gallons, and the sources of the water. I have simply included some data which I happen to have, with no attempt at completeness. Most of the statistics are for 1892 or 1893, but those of St. Petersburg and Warsaw are for 1890, and for the English cities, except London, the figures are taken from a local government report for 1887. Most of the figures are calculated from pumping records for an entire year; the statistics for the gravity supplies at Paris and Vienna may be less exact. The Munich and Frankfort supplies are also gravity, but the figures given are calculated from comprehensive weir measurements.

FILTERED RIVER WATER SUPPLIES.

City.	Population supplied.	Million gallons daily.	Gallons daily per head.	Sources.
London, 7 companies,†	5,030,000	190,	38,	Thames and Lea
Berlin,	1,606,000	26,	16,	Harvel and Spree
St. Petersburg,	960,000	39,	40,	Neva
Hamburg,	583,000	32,	53,	Elbe
Warsaw,	500,000	6,	12,	Weichsel
Breslau,	335,000	7,	22,	Oder
Rotterdam,	240,000	13,	54,	Maase (Rhine)
Magdeburg,	200,000	5,	24,	Elbe

FILTERED WATER FROM SOURCES OTHER THAN RIVERS.

Amsterdam,	515,000	10,	20,	Dune and canal
Liverpool,	815,000	22,	27,	Storage reservoir
Bradford,	364,000	12,	33,	" "
Dublin,	327,000	18,	55,	" "
Birmingham,	600,000			" "

GROUND WATER SUPPLIES.

Paris,*	2,500,000	53,	21,	Springs
Vienna,	1,000,000	23,	23,	"
Budapest,	500,000	22,	44,	Wells by Danube
London (Kent Co.), . .	460,000	16,	35,	Wells in chalk
Leipsic,	360,000	5.5	15,	Wells
Munich,	300,000	11.5	38,	Springs
Dresden,	280,000	6.0	21,	Filter gallery by Elbe
Cologne,	255,000	11.5	45,	Wells by Rhine
Frankfort-on-Main . .	186,000	6.7	36,	Wells and springs

UNFILTERED SURFACE WATER SUPPLIES.

Manchester,	963,000	24,	24,	Storage reservoir
Sheffield,	324,000	—	—	" "
Glasgow,	794,000	50,	64,	Loch Kathrine

SIX LARGEST AMERICAN WATER SUPPLIES FOR COMPARISON.—*American W. W. Manual, 1890.*

Chicago,	1,099,850	152,	140,	Lake Michigan
Philadelphia,	1,046,964	138,	132,	Rivers
New York,	1,515,291	121,	79,	Storage reservoir
Brooklyn,	776,838	55,	72,	Wells and reservoir
Buffalo,	255,664	47,	186,	River
Boston,	527,606	42,	80,	Storage reservoir

* In addition, 80,000,000 gallons of river water are daily used for public and manufacturing purposes.

† Exclusive of ground water.

THE LAKE VYRNWY WATER SUPPLY FOR LIVERPOOL.

BY THOMAS M. DROWN, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

(Remarks at the meeting of November 21, 1894, illustrated by photographs.)

THE large cities of England must necessarily be dependent, for their ever-increasing water needs, upon drainage areas far distant from those cities, if sparsely settled regions are to be drawn upon.

Glasgow has for thirty-five years enjoyed a pure supply from Loch Kathrine, and Manchester has just completed her aqueduct to Lake Thirlmere, a distance of 96 miles.

The sparsely settled condition of much of the mountainous portion of central Wales makes this region an attractive source for water collection, and two large English cities have availed themselves of suitable valleys in this region. The Liverpool reservoir, in the valley of the Vyrnwy, is now complete, and that of Birmingham, at Rhayader, has just been begun.

Not only are the collecting areas favorable as regards small population, but the rainfall is very heavy, amounting to nearly 70 inches.

I had the pleasure, last summer, of visiting the new Vyrnwy supply of Liverpool, concerning which so much has recently been written. The Vyrnwy was a stream of very variable flow, which, in the dry summer time, did not amount to two million gallons per day, while in the wet seasons there were often destructive freshets. The daming of this valley formed a lake having a superficial area of 1,121 acres, a length of 4½ miles, and an average width of half a mile. The greatest depth is 84 feet. This lake contains, when full, 13,125,000,000 gallons of water. The area of the gathering ground is 18,000 acres, but the city of Liverpool has the power to divert two neighboring streams, with an additional gathering ground of 5,200 acres. It is estimated that the rainfall on this combined area of 23,200 acres will yield an average daily supply of 53,000,000 gallons, of which 40,000,000 will be available for Liverpool after delivering compensation water as provided by an Act of Parliament.

The compensation water demanded by the Severn Navigation and Fishery Commissioners is 10,000,000 gallons per day. This very liberal compensation was accepted by the Liverpool Corporation. But, much to their surprise, Parliament, while the bill was before it, imposed very unexpectedly an additional compensation of over 1,200,000,000 gallons a year in "freshets" of 40,000,000 gallons each, whenever the Severn Commissioners may require. These "freshets," which are a very severe

drain upon the reservoir, and which involved the raising of the dam five feet higher than was originally intended, are supposed to be beneficial in connection with the breeding of fish and the scouring of the Severn.

The following are the principal dimensions of the dam :

Total length along the top, 1,165 feet.

Height from the lowest part of the foundation to parapet of carriage way, 161 feet.

Height from river bed to sill of overflow [under the roadway], 84 feet.

Greatest thickness at base, 120 feet.

Width of roadway over top of dam [between the parapets], 19 feet 10 inches.

Batter, or slope, of the wall on the front, or water side, 1 in $7\frac{1}{4}$.

Slope of back of wall, 1 in $1\frac{1}{2}$.

Total quantity of masonry in the dam, 260,975 cubic yards.

Total weight of the masonry, 510,000 tons.

Quantity of earth and stones, excavated for the foundation, 220,890 cubic yards.

Refilling at the front and back of the wall, 79,501 cubic yards.

The cost of the masonry was £530,000, and the total cost of the dam, £601,500.

A fine new road, nearly 12 miles in length, including the beautiful viaduct over the dam, completely encircles the lake; it is from 20 to 30 feet in width.

Nothing was removed from the valley before flooding except trees or lumber and stone which had value. There was no attempt to remove vegetation or soil. With us in Massachusetts, such neglect to remove organic matter would have resulted in very foul water, but there has been no inconvenience from this source as yet, as I was informed by Mr. Parry, the water engineer of Liverpool. The lake was stocked with trout from Loch Leven, and during the first year they grew to enormous size, making the lake a favorite resort for fishermen. The fishing is said to be still good, although the trout are not as large as they were when they had the abundance of food afforded them during the first year.

One reason why the water does not become foul may be that the compensation water, which is drawn off near the bottom of the reservoir, to some extent prevents stagnation. It is true that, during the first year, the bottom water was discolored and had a bad odor, but this condition of affairs, according to Mr. Parry's statement, does not now exist. Moreover, there is not that great difference in the temperature between the water at the surface and that at the bottom which there is here during the summer. I could not learn that anywhere in England is the organic matter removed from the bottoms and sides of valleys before flooding for reservoirs, or that any bad consequences result from this neglect. If this is the case, the immunity from trouble must be due to the prevalence of a lower average summer temperature.

The straining tower, situated about three quarters of a mile from the

dam, is an ornamental structure standing in 50 feet of water and 104 feet above the surface, and 30 feet in diameter. It forms the entrance to the aqueduct. Two columns of pipes, 3 feet 6 inches in diameter, outside the tower, are so arranged that water can be drawn from any level of the lake. The water is strained through a cylindrical screen of fine copper wire [gauge 14,400 meshes to the square inch] 9 feet in diameter and 25 feet high. When the screens are clogged, a bell on the tower is rung automatically, calling the attendant to clean them. The screens are lifted into the body of the tower and are there washed by jets of water supplied by a special reservoir on the hillside.

The aqueduct is nearly 69 miles long, and, with the exception of four miles of tunneling, consists of cast-iron pipes from 39 to 42½ inches internal diameter. Eventually there will be three pipe lines to Liverpool, each with a capacity of 13,500,000 gallons a day.

At Oswestry, about 19 miles from Lake Vyrnwy, are situated the filter beds. At present there are three filters, with a total area of 24,000 square yards. The filtration is conducted according to the usual English system. The filters are scraped when the loss of head is from 12 to 18 inches. The lake water is brown in color, and about half of the color is removed by the filters.

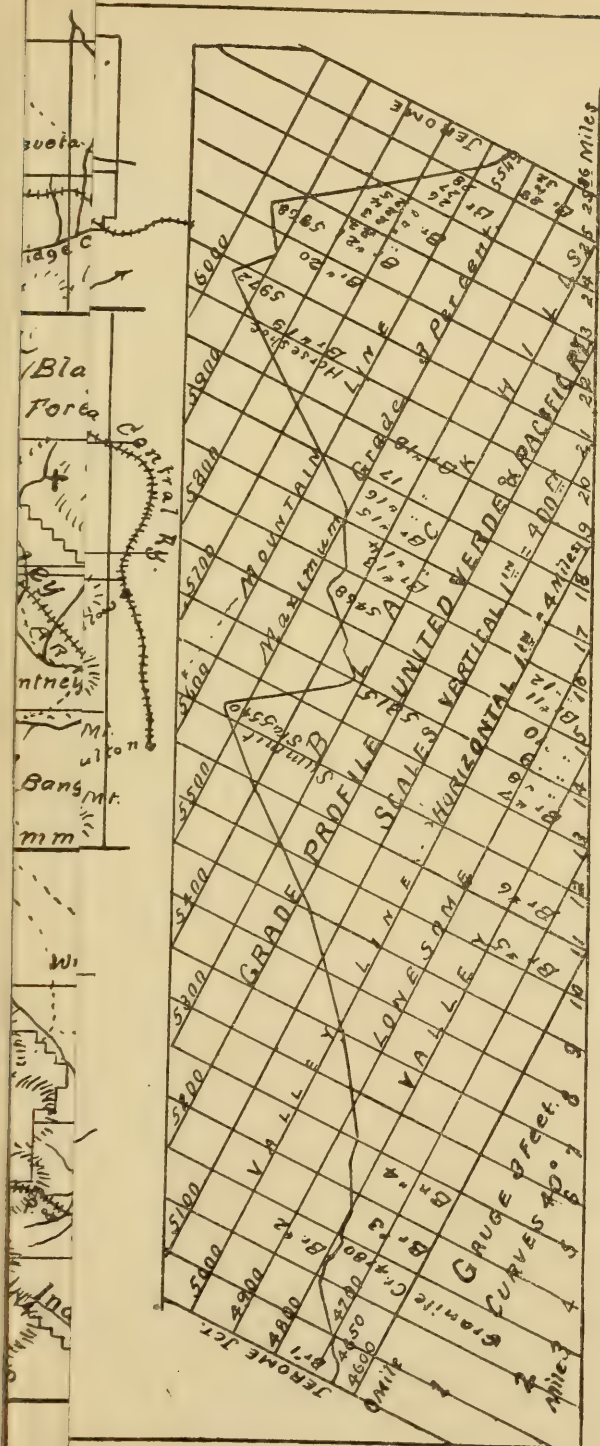
A mechanical analysis, by Mr. Hazen's system, of a sample of the sand used in these filters, showed that 10 per cent. of it was finer than 0.3 of a millimeter, and indicated a maximum filtration rate of 60,000,000 to 70,000,000 gallons.* At the time of my visit in June last, No. 1 filter, having an area of 1.65 acres, had passed 171,000,000 imperial gallons between scrapings.

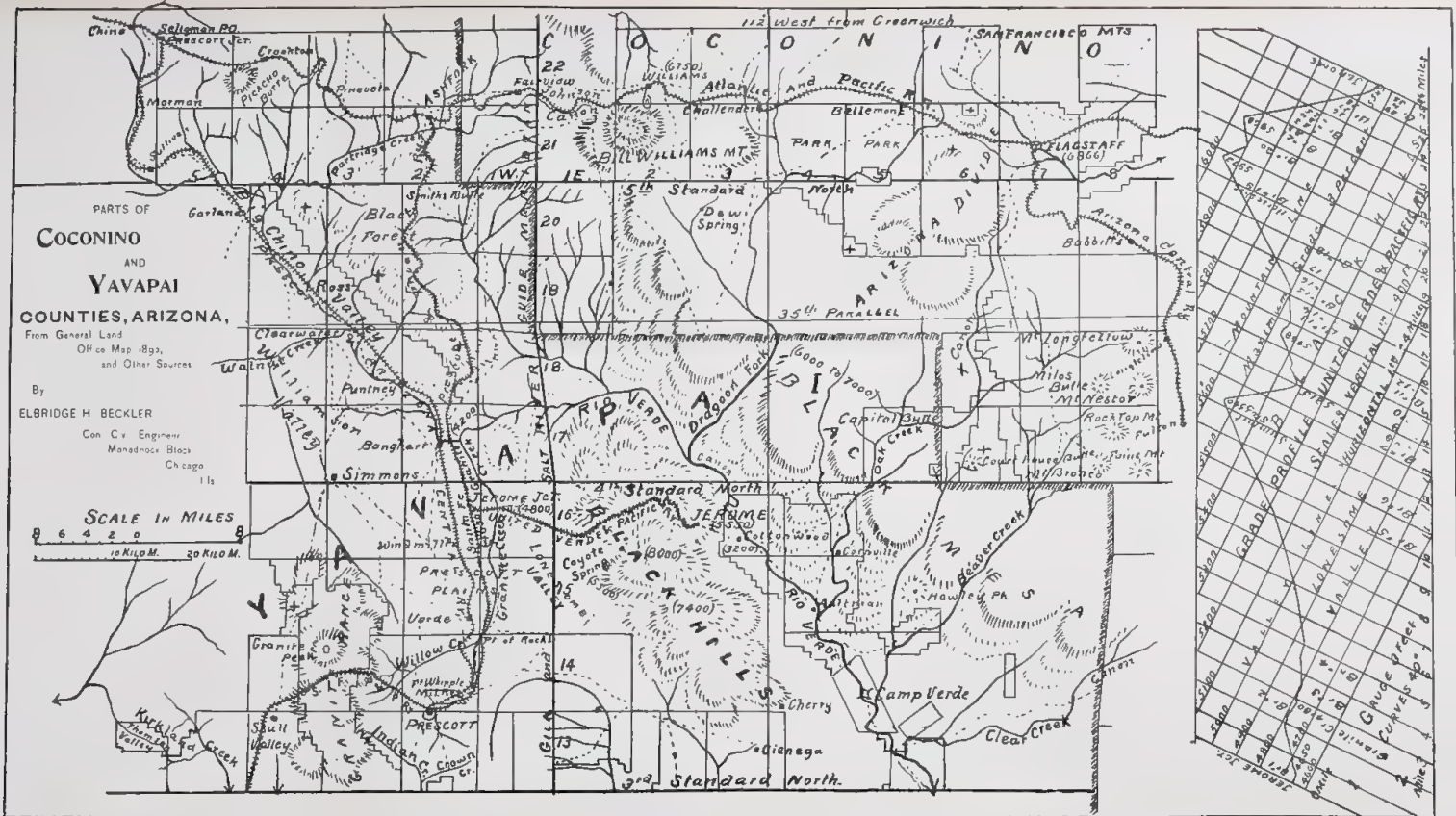
The Liverpool water works, which include also reservoirs and filter beds at Rivington, with a capacity of 12,000,000 gallons a day, and wells in the New Red Sandstone yielding 6,500,000 gallons a day, are all under the charge of Mr. Joseph Parry, water engineer, to whose courtesy I am indebted for my information concerning these works.

* See "Some Physical Properties of Sands and Gravels, with Special Reference to their Use in Filtration." By Allen Hazen, Mass. State Board of Health; Twenty-Fourth Annual Report, 1892.









THE UNITED VERDE AND PACIFIC RAILWAY.

BY ELBRIDGE H. BECKLER, MEMBER OF THE MONTANA SOCIETY OF
CIVIL ENGINEERS.

[Read February 9, 1895.]

THE subject of this paper is situated a little easterly from the centre of Yavapai County, Arizona, twenty to thirty miles northeasterly from the town of Prescott. It is a three-foot gauge railway, twenty-six miles in length, and lies along the easterly and northerly slopes of the Black Hills of Arizona, and extends westerly from these hills about ten miles, the termini being, at the east, the United Verde Copper Company's works at the town of Jerome; and at the west, Jerome Junction, a connection with the Santa Fé, Prescott and Phoenix Railway.

Personal capital for private use in transporting the product, and furnishing supplies for the operation of the United Verde Copper Company's mines, properties owned principally by Mr. W. A. Clark, of Butte, Montana, brought this railway into existence. The road performs the usual duties of common carriers, having duly qualified by incorporation, complying with United States and Territorial laws, accepting the conditions, restrictions and limitations, and receiving the usual benefits, of roads constructed for public use and convenience and dependent upon such use for the return of its operating expenses and interest on capital invested. While the public use helps slightly, it is a trifling matter, and had no influence in the origin, development or perfection of the enterprise.

The conditions which made it desirable to construct this road; the character of road which could be constructed so as to be profitable—that is, furnish cheaper transportation than by other means; the principles which should govern in making an economical location, as regards details of construction, are some of the questions which would present themselves to an engineer called upon to investigate the situation. A few facts bearing upon these matters will be mentioned before entering upon the description of the road and the details of construction, that those who read may judge of the fitness of the work.

Reference to a map of Arizona shows the Black Hills a disconnected group of mountains lying in latitude 34° to 35° and longitude $111^{\circ} 45'$ to $112^{\circ} 15'$, covering an area of ten by thirty miles, and with the major axis bearing 30° west of north. The Verde River heads northwest of these hills, with some of its southern tributaries rising in the Granite Range, from which the water flows northward along the

west side of the hills to the junction with the main river. The river then passes by the north end of the mountains and flows southerly by the east side. In this way the Verde and its tributaries almost completely encircle the group of mountains.

The United Verde Copper Company's mines are located on the northeasterly side of the mountains, overlooking the Verde River, from which they are distant about three miles. The mines are at an elevation of 5,500 feet above sea level; the river at this point is 3,200 feet above sea level, and the top of the mountain about 8,00 feet. The top of the mountain is covered with a fairly good quality of pine timber; that within a few miles of the works has now mostly been cut in supplying wood and mining timbers, and lumber for buildings.

East and north of the river the country rises abruptly to an elevated plateau (elevation between 6,000 and 7,000 feet) of extensive area, reaching northerly beyond the Atlantic and Pacific Railroad to the breaks of the Grand Cañon of the Colorado. There are large bodies of pine timber on this plateau. West of the Black Hills are the valleys of these southern tributaries of the Verde, which flow northerly, the principal one being Granite Creek. The bed of the stream is ten miles from the foot-hills, a long, gentle slope covering this distance, starting at the foot-hills with an elevation of 5,200 to 5,500 feet, and descending to about 4,800 feet, opposite the north end of the mountain, at the creek, and 4,200 feet at the junction with the Verde River. The Santa Fé, Prescott & Phoenix Railway comes into this Granite Creek depression at about the nearest point to the mountain, and about seventeen and a half miles from Jerome, by air line.

From Jerome a wagon road climbs over the mountain, through a pass about 7,000 feet high, and, after reaching the foot-hills on the westerly side, divides, with one branch extending to Prescott and another to Massick's Station. A wagon road also extends down into the Verde valley from Jerome, making a descent of 2,500 feet in about four miles.

The early workings of the mine consisted of making an open excavation in the mountain side, where a large body of red oxide copper ore, rich also in gold and silver, was exposed on the surface. It has been stated that several millions of dollars were shoveled up and hauled away before any attempt was made to find and follow the mineral vein. A large sum of money was spent in constructing a wagon road to the A. & P. R. R. at Ash Fork, then the nearest or most practicable outlet to rail transportation. Lack of experience and reckless expenditures caused the failure of the parties owning the property, after their surface riches began to diminish.

When Mr. W. A. Clark purchased the property, development was

begun in earnest. The obstacle in the way of demonstrating the great value of the property was the expensive wagon haul. The best outlet was over the mountain road to the Prescott and Arizona Central Railway, twenty-five miles to the point where Massick Station now is. The Prescott & Arizona Central Railway went out of business in 1893, when the Santa Fé, Prescott & Phoenix Railway was constructed through the same section of country. This wagon road had two hills to pass over in each direction, with a rise of about 1,500 feet in each place. The grades on these hills in some places reached 16 per cent., and for long distances exceeded 12 per cent. The heavy teaming made it necessary to keep quite a force on the road, at all times, to keep it in repair. The soil on the mountain, where there was any, and also in the valley west of the mountain, is of a peculiar nature. A little rain or snow changes it into a lively mixture resembling quicksand. Horses sink into it to the fetlock, and lightly loaded wagons settle down to the hubs. In good weather, with good roads, a freight team could make a round trip a week. After a few days of showery weather the road became practically impassable.

Owing to the nature of the road, it has been necessary to shut down all work of producing from the middle of November to the middle of April each year, working the mine but eight months, although quite a force would be kept through the winter, making developments and doing other necessary work on the property. It was the aim to have supplies, and everything necessary for hibernating, prepared before the roads became bad, but invariably the matter was put off a little too long, and the last shipments, in and out, were attended with great expense and difficulties. An annual rainy spell in July and August always made the road useless for from one to three weeks. The value of the property has been much affected by the necessary closing down of four months each year.

There were several attempts to introduce tramways and inclined railways to pass over the mountain. Several surveys for different schemes were made, and enough work was done to leave marks which are still visible in various places. In 1891 the Link Belt Engineering Company undertook to put in a cable tramway over the mountain, from the works to the west side, to deliver and receive freight at the foot of the westerly hill, from which point there was a comparatively easy wagon road to the railroad, twelve miles away. A branch railway, or spur, was also planned to connect with the tramway. The system proposed consisted of towers, or posts, every 20 feet, carrying two rails on a cross-arm. Travelers, to which were suspended buckets, boxes and hooks for the carriage of matte, coke, wood, etc., were placed on the rails every 100 feet and connected by cables. The cable passed around a drum or

wheel at the ends, and wherever an angle was necessary, and at the power house.

The company built the tramway but could not make it work. It was proposed to handle five miles of tramway from a single power station. There were many changes of grade, dipping down sharply into valleys, and rising abruptly over sharp ridges, in the attempt to get a short direct line. There were some angles where it was necessary to change direction. When power was applied to the cable, the wire, with the traveler and buckets, was lifted from the towers and track, crossing the valleys. There was then a great strain on the cable and supports at the summits, and at the angles. After working on the tramway until the spring of 1894, two and a half miles were made to operate by putting in two power stations, in this distance, and by relieving the more abrupt changes of grade and alignment.

During the working season of 1894, all the product of the mine was taken out over the tramway, and coke was taken in. Some wood, cut on the top of the mountain, was taken in by the same way in the last two months. On account of the difficulty in making roads on the steep and rocky slopes of the mountain, all this wood used at the works in smelting, and in several hundred pits of the open air roasts, has been packed from the mountain top on the backs of burros. Nearly all that was convenient to the works has been cut in order to keep up the supply of twenty cords a day, until now there is scarcely any within a distance of four miles.

It was becoming urgent to have some other means of getting wood, or other fuel. In addition to the wood, the furnaces consumed daily about thirty tons of coke. The coke and other supplies, and machinery, gave about as great a tonnage towards the works as the product, in matte and bullion, gave in the other direction. The plant had grown rapidly by frequent additions, until the daily capacity of the works was about sixty tons of matte and bullion.

Several surveys for a railroad to get out to other railroads had been made. The difficulty of reaching the place, going around, or over, so steep a mountain, the expensive construction, and the uncertainty of future traffic, made railroad companies hold off. The mine is now opened to a depth of five hundred feet, and ore has been taken out to a depth of less than three hundred feet. In the winter of 1893 Mr. Clark decided to construct the railway at his own expense.

At this time it would be fair to assume that the daily traffic to and from the works was about one hundred tons, handled at a cost of eight dollars per ton, not including twenty cords of wood at five dollars per cord, with this latter item becoming rapidly more expensive. The plant had probably cost more than \$1,000,000. No other mines have been discovered in that immediate vicinity.

With the foregoing facts, or conditions; the question for decision was, what kind of a railroad should be constructed.

The problem for solution was, in some respects, easier than the location of a road for public use, dependent upon general traffic. As seen above, the wagon haul was costing eight dollars per ton. A portion of the tramway becoming useful (after it was decided to build a railway) probably reduced this cost to five dollars per ton. The exact cost of the tramway may never be known. It was not far from \$70,000, but, as it is not yet decided who had to stand this expense, on account of its failure, the cost is left out. Five dollars per ton would maintain a tramway and transport the metal, and coke or coal, over the tramway and wagon road. Machinery and other bulky articles would still require the use of wagons the entire distance. The construction of the balance of the tramway, and the short and cheap railroad spur, might further reduce the working cost to four dollars per ton. It will readily be seen that there was little danger of making the road unprofitable by reason of excessive cost, when there was a possible limit of four dollars per ton to be expended in operating expenses, maintenance, and interest charge, in transporting one hundred tons daily a distance of twenty-six miles. A few figures will show that one dollar per ton, or one hundred dollars per day, would be sufficient for maintenance and operating, which would leave three dollars per ton, or three hundred dollars per day, for interest charge. This sum, capitalized at 6 per cent., shows that over \$50,000 per mile could be spent in construction and equipment.

This might be a proper way to figure if the railroad was to be built for perpetuity, with a growing traffic, by reason of a greater development of the country. The life of the mine is unknown; in ten years it might be abandoned; or, by reason of the discovery of other mines in that section, a more extensive smelting plant would be more favorably situated at some other point. A great increase of traffic might require such a change in service that a road constructed for present needs would be entirely unsuitable for the work, and the necessary changes would be equal to the construction of a new line. It would be unreasonable to construct and equip a first-class road for twenty daily trains while the present business would require but one train.

In view of these conditions it would be fair to assume that the price per ton should contemplate the refunding of the capital expended, in a period of twelve years, as the probable time when the proposed road would reach the end of its usefulness. Figures show that four dollars per ton would provide for maintenance, operation, interest on capital, and refunding of capital in twelve years, with a construction cost of \$35,000 per mile. This demonstrates that there was no danger of exceeding the safe limit.

In the further consideration of what would be a justifiable expenditure for the traffic it became evident that there was no occasion to approach very near the cost of wagon, or tramway, rates, but it was not desired to carry economy in construction to a point out of proportion with economy in operation.

The number of daily trains is a factor affecting cost of transportation and of maintenance, and thus influencing the question of location. The minimum train service is, of course, one full crew, and in this case it was desirable to so proportion the engines and grades to the traffic that one crew should be able to do the daily work, and with one trip per day, if possible, although the mileage (twenty-six miles) would not prohibit two trips if necessary.

The question of gauge for such a road is an important one. Able writers, and engineers, have in the past discussed this question in its application to all railroads. The question here, where there was a connection with another railroad at one end only, is not so broad.

Many of the arguments for and against a three-foot gauge, as compared with the standard 4 feet 8½ inches, are not capable of expression in money value. We find, for narrow gauge, cheaper construction by reason of using sharper curves on a mountain side, reducing heavy cuts and high, expensive bridges, crossing chasms; narrower roadbed; lighter bridges, and lighter rails, ties and fastenings. There would probably be not much difference in the cost of equipment, as the smaller number of cars required for standard gauge road would nearly offset the difference in cost. By using principally cars of other roads, the standard gauge equipment could be made to cost less than the other. The engines, to perform the same service, might cost 20 per cent. more on the standard gauge road, but it would probably be economical to purchase engines capable of doing 50 per cent. more work, at an increase of cost of 30 per cent.

Maintenance of the narrow gauge is more expensive by reason of the greater amount of curvature, but less expensive on account of the lighter track material and lighter rolling stock. On the whole, maintenance expense is probably less on the narrow gauge.

Transferring from the cars of one gauge to the other does not make much additional expense, especially with traffic of such a nature as is found in this case. The incoming material is principally coal and coke, loaded in box, stock, or gondola cars, from which it is necessary to shovel it. By unloading these cars into bins, from which the coal and coke can be drawn out below, into narrow gauge cars, which can be unloaded by drop bottoms and side gates, there is scarcely any more handling than if the broad gauge cars delivered the material at the destination. There is an additional expense in switching.

The outgoing product, metal and bullion, has to be handled once extra, but this is in such shape (in sacks) that it can be very cheaply transferred by trucking from car to car.

The use of foreign cars on such a short road would show a car mileage balance against the road at all times. The few cars owned by the road would be away from home, widely scattered, and probably standing on side tracks, earning no mileage (unless the per diem system came into practice) nine-tenths of the time. By using broad gauge and foreign cars the car repairing account would be largely increased. The old cars of other roads are always finding their way to small roads, in out-of-the-way places, where they undergo repairs before returning home.

The clerical force for the short narrow gauge road is rendered much less by dispensing with all the help usually employed in the car accountant's office.

As it was possible to do the required daily work with one crew on either gauge there would be no material difference in cost of train service.

While no careful location for a standard gauge road was made, sufficient data were obtained to show that the cost of roadbed, bridges and track material would be increased not less than 80 per cent., or reduced to the cost of hauling the traffic, would add an interest charge equivalent to twenty cents per ton.

There was little choice as to route. The works being situated 2,300 feet in elevation above the Verde River, any practicable grade making the descent would be developed so far westerly around the mountain that the only proper thing to do would be to connect with the existing road near at hand, although there were many reasons for desiring a connection directly with the Atlantic and Pacific Railway, without the intermediate line of the Santa Fé, Prescott and Phoenix Railway.

The junction point was selected at a place where water could be obtained, the line being lengthened about 3,000 feet for this purpose. Water is scarce in Arizona, and there are long stretches where none can be found. With no water along this line it was quite necessary to have a water station at each end.

The difference in elevation between the termini is about nine hundred feet. It would have been possible to make a descending grade from the mine to a point on the Santa Fé, Prescott and Phoenix Railway, by passing around the mountain with a great loss of distance.

The mountain sides are cut by great ravines occurring frequently, with only sharp ridges between, which extend for a mile or more, without much change of elevation in the crest. To pass around one of these ridges from one gulch or chasm to the next would require a detour of

over a mile to advance less than one fourth the distance. There appeared to be less difficulty in crossing these ridges near the point where they started out from the main body of the mountain, or through some saddles or depressions in the spurs, not far distant from such point.

The selection of these places to give the shortest line and cheapest construction gave some undulations to the grade not otherwise necessary. This also influenced to some extent the selection of the maximum grade. There were two such spurs in the first three and a half miles next Jerome, where any lighter grade would have added materially to the length of the line. A level or descending grade, out of Jerome, would have carried the line several miles northward to pass around projecting spurs. So long as the maximum grade was kept down so as not to affect the handling of the daily business with one train, this feature was not considered very objectionable.

The selection of the engine for the work was made with the probable grade in view. The sharp curvature to be used demanded that the rigid wheel-base of engine should be as short as practicable. The attempt was made to adjust these factors of grade and curvature, affecting train capacity and construction cost, to the weight and class of engine so as to produce the most economical condition in operation.

A Mogul engine, with 9 feet rigid wheel-base, was able to do the work on a 3 per cent. grade, and could be made to pass over curves of 100 feet radius. For greater ease and comfort the limiting radius was made 146 feet, except in one instance, where 162° were turned with 130 feet radius. This sharp curvature was needed in crossing the ridges without excessive cutting or tunnels; in crossing the gulches without very high bridges, and in placing the line closely on the side-hills to make a roadbed chiefly in cutting, for greater permanence, or where the steepness of the hillsides prohibited the building of embankments. For fully one-half the distance of the 13.66 miles on the mountain the natural slopes were not flatter than 2 to 1, and for the balance there were few places where it was flatter than 3 to 1. Using 40° curves gave cutting at the crossing of ridges from 10 to 25 feet in depth (in one cut 48 feet). The crossing of gulches with similar curves gave bridges from 25 to 48 feet in height. The excavations on the mountainous portions amounted to 110,000 cubic yards, against 150,000 cubic yards embankment with practically no waste excavation, with a 300 feet haul, while the comparative lengths of cut and fill on center line, for the full distance, are 47,430 cut to 20,500 fill, omitting 3,350 lineal feet in bridges.

This gives an idea of the steepness of the slopes encountered.

The maintenance of roadbed is an important matter, and, in that

section of country, this would be attended with much less expense, with the light train service, where the track rested upon original ground in an excavation, than where high, or side-hill, embankments were made. Some additional curvature was used in so constructing the road as to avoid borrowing for fills.

The grading in the valley amounted to 4,000 cubic yards per mile, exclusive of terminal grounds. The roadbed here was principally in embankment. On the mountain, the work averaged per mile: earth excavation, 500 cubic yards; loose rock, 2,000 cubic yards; solid rock, 5,500 cubic yards; ballast (in the excavation only), 1,000 cubic yards; and borrow, 1,000 cubic yards, making a total of about 10,000 cubic yards per mile.

The location of line was begun May 14, 1894. The mountainous portion of the line (13.66 miles) consumed the time of a party of eleven men about seven weeks, making a progress of about one-third of a mile per day. The alignment gives an average of 727° of angle per mile (2 full circles), and the average length of tangent is 166 feet. There was no preliminary line, except that run from day to day by the location party. There was no water near the line, except at the ends. There is a spring four miles south of line on the west side of the mountain. This made the extreme haul of water eleven miles. During the survey, the camp supplies and water were packed on burros. The difficulties of transportation, and even of walking, can be understood by the statement of a member of the party, made one Sunday afternoon. He said "We have had no water since yesterday at 4 o'clock." The distance from the camp to Jerome, where there was plenty of water, was only four and a half miles by trail, and the party did not work Sunday. It cost \$5 a day to pack water and supplies to this camping ground for the engineering party.

The maximum grade (3 per cent.) was equated for curvature at the rate of 0.03 foot per degree. As the curves were very frequent, with short tangents between, often less than one hundred feet, the compensation for curvature was distributed so as not to make changes of grade for distances less than three hundred feet. It is impracticable on any road to have grade changes maintained at the precise ends of curves, and it is better, in all cases, where tangents are short, to limit the changing points to not less than five hundred feet, using an average grade extending over curve and tangent, which will allow the proper amount of compensation.

No reverse curves were allowed, the minimum tangent being fixed at 60 feet. This might better have been made 100 feet. It would probably have been better to have made this limit 150 feet, or even 200, as in most cases the lateral movement of the center of the curve of 100

feet length, in doubling its length, does not add very much to the cost of work, and the character of the alignment of road is much improved by not having changes of direction made too abruptly.

Examination of the map of the line will show a place where it would appear to be desirable to construct a tunnel, and where 400 feet of tunnel, with not very heavy approaches, would shorten the line 4,700 feet. Seven thousand dollars were spent in grading the longer line around the hill. The tunnel would probably have required a timber lining, and the cost of timber would have been great. All supplies, powder and water would have had to be packed to the work, or an expensive wagon road would have had to be constructed. The difference in cost, now, with the railway in operation, will justify the spending of the \$70,000 for a temporary line.

When construction was begun, a wagon road was built along the westerly portion of the mountain work. On the easterly end, burros were used for packing all supplies, powder, tools and water.

The grading was begun the 23d of May. The scarcity and expense of water for stock, the difficulty of getting cars and track, or carts, made it best to use wheelbarrows as much as possible in moving the material from cuts to fills. A few mining cars, pushed by men on light tee rail, were used on the east end, and eight carts were in service on the westerly end in making the longer hauls. Débris can be wheeled but a short distance with profit at the usual prices. It was also found that it cost more to handle carts in the narrow cuts and on narrow banks, than is usual on broad gauge roadbed.

The work of grading was mostly done by contract, the railway company furnishing all supplies and tools for purchase by the contractor. The amount of work given to any party was based on the engineer's judgment of the ability to handle; in some places a single cut being let to a gang in partnership for that piece of work only. The cost of hauling water eleven miles was found to be four cents per gallon, and five gallons per day per man was about the amount required.

Packing on burros cost five cents a gallon for four miles; this sum probably gave some profits to the packer, who drove eight burros, each loaded with twenty gallons.

The roadbed was made twelve feet wide at grade in cuts, and twelve feet wide on top of embankments. Excavations were made one-half foot below grade for ballast. The material being mostly rock, making fair ballasting material, six inches of the broken stone were put in by the grading contractors preparing the surface for the ties. The roadbed was brought into excellent surface, the engineers setting grade pegs every twenty-five feet, generally, giving the proper elevation for curves. The fine condition of roadbed was a great help in track-laying,

as it would have been almost impossible to use any track until surfaced, on account of the numerous sharp curves, if the roadbed had been rough.

The grading was prosecuted so that tracklaying could begin at the the west, and not be delayed for roadbed.

Nearly all the material for bridges had to be taken to the bridge sites by team, or had to be hauled ahead by wagons on the grade. There was very little opportunity to haul ahead on the grade, as there was seldom a half mile without a bridge, and it was not practicable to get across the gulches with wagons loaded with timber. It would have added largely to the expense to attempt to construct bridges far ahead of the rails.

The bridges were mostly trestle bents on subsills, with spans of nearly sixteen feet, excepting at a few places, where piles could be driven. The pile bridge had three piles to the bent, with 14-foot spans. The trestle bents had four posts (two batter and two plumb) under a ten-foot cap of 12 by 12 timber. There were six stringers, 7 by 16 to the span. Bridge ties were 6 by 8, 12 feet long, spaced 15 inches centers, and a guard rail 5 by 8 was dapped down on the ends of the ties. The posts were of round timber, standing on flattened sills.

The round timber was procured on the Mesa, on top of the mountain, and was run down to the line in slides, where it was impracticable to construct a cheap wagon road. It was necessary to load most of it on cars, to be hauled forward as the track progressed. The heights for trestles were determined in advance, so that all framing of posts and sills was done before loading on cars. The most of the bridges were on curves and the elevation was framed in the posts. The subsills were cross ties cut in two pieces, as the price of ties was no greater than other timber. They were more convenient for handling, and gave the liberty of using a greater or lesser number of pieces under each bent, depending upon the nature of the foundation. Generally, twelve pieces were sufficient for each bent. Sawed timber was furnished by sawmills located at Williams, on the Atlantic & Pacific Railroad, about sixty-five miles distant.

The bridges were built by contract at a price per thousand feet B. M., the railway company furnishing the material. The foundations were prepared by day force working for the railway company, and were always ready in advance of the bridge crew.

A sufficient crew was kept erecting bridges to enable the structure to be set up with the least possible delay for all parties. That is, it was planned to have each structure ready for crossing as soon as the track to that point had been surfaced, one crew being used for both tracklaying and surfacing. The bridge crew would finish up all bracing,

spiking and placing of guard rails while the track would be advancing to the next structure. There was not a day of idle time for either force during the construction of twenty-six bridges and the laying of thirteen miles of track.

Track-laying was begun on the 13th of August. Across the open country, twelve miles at the west end, rails were laid from an iron car, and ties were distributed with teams. On the mountain, teams could not be used while the track-laying was progressing, as it was not possible to get on or off the grade except at a few places. The bridge sites (gulches) prevented hauling ahead while the bridge was being built. The frequency of the bridges prevented working nights, as generally but one day's laying could be made ready at a time. Hence the idle time of the teams would have added to the expense.

It was found best to use a car similar to the iron car, on which about 125 ties could be piled on two rails. A heavy wagon and team of horses were placed on the grade just ahead of the rails, and the ties were thrown on the wagon, hauled ahead and distributed to half tie the track, while the iron and tie cars went back for other loads. The balance of the ties were placed under the rails by a crew working just ahead of the spikers. This method worked better with the light, short ties, 6 by 7, 6 feet long, than it would with heavier ties on a broad gauge road. It was not practicable to use any of the track-laying machines, with side carriers for rails and ties, where the curves were so sharp.

The track force consisted generally of fifty men, divided as follows: A superintendent, 8 iron men, 4 strappers, 1 peddler, 10 spikers, 5 nippers, 2 tie-spacers, 4 tampers, 3 drivers and 12 tie-buckers.

This gang could generally lay a half mile in half a day, and the amount of material was about a train load. The other half of the day would be spent in surfacing and filling track while another train load was being brought forward. Where the distance between bridges was more than half a mile, sufficient material would be brought to the front to permit the track-laying to continue to the bridge site before the surfacing was done. In surfacing and filling track across the twelve miles of valley work, teams and scrapers were used. Material was scraped from the borrow pits, thereby preventing the robbing of embankments. This made the work quite economical. The teams could not be worked to advantage in cuts, nor where embankments were more than three feet high. Eight teams could fill a mile per day.

The rails were rolled at the Colorado Fuel and Iron Company's Works, Pueblo, Colorado, 45-pound steel being used on the mountain and 40-pound section on the valley work. The 45-pound section was the Denver and Rio Grande Railroad pattern, with sloping sides to the

head. The 40-pound section was practically the American Society of Civil Engineers' section, with vertical sides on the head. Angle bars 24 inches long, with four holes, were used for suspended joints. The same bar fitted either pattern of rail. The switch material was all designed for the 40-pound section, the yards being laid with that rail, to avoid confusion. The switch stand was the Banner pony stand.

Rail braces were used on all curves, five to the rail on the outside of curve only. The brace was the Colorado Fuel and Iron Company's wrought brace, which takes two spikes, and fits closely under the head.

Guard rails were placed on the inside of the inner rail, on all curves of 30° or over. This guard rail was of the 40-pound section, and was placed close enough to the track rail to let the flange of the wheel press against it, before it would permit the flange of the outer wheel to crowd very hard against the outer rail. It was found necessary to put rail braces against this guard rail, to prevent its being overturned, thus showing that it was quite effective in preventing the wheels from crowding or climbing over the outer rail.

It might have been possible to save the expense of guard rails on curves of 30° or a little more. The guard rail is an extra precaution against derailments; and on such steep mountain sides an accident might be attended with great damage to property and possible loss of life. It might be advisable to economize in the use of guard rails by taking care, in location of such lines, to make a limit of about 24° for curves without guard rails, taking slightly heavier work, and then using only curves approaching the sharpest, or maximum, curve permissible at all places requiring sharper than 24° . There is a natural tendency, however, for a locating engineer to use the curve that, according to his judgment, fits the place, regardless of such consideration.

There were no derailments on any sharp curves during the time the road was operated by the construction forces. The rails were all curved at the material yard at the junction before moving to the front. The foreman was supplied with the alignment table showing the number of curved and straight rails required for the track, and rails were sent forward exactly as needed. The curves were numbered from the beginning, and the rails for each curve were marked in paint with the number and degree of curve. Rails were laid with broken joints, and 28-foot rails were put in as needed, to keep the joints nearly at the center of opposite rails. Seventeen ties to the 30-foot rail were used on curves, and fifteen ties to the rail on tangents.

At the junction with the Santa Fé, Prescott and Phoenix Railway there were constructed coal and coke bins, with elevated tracks, for the broad-gauge cars to be run upon, for unloading into bins, from which the narrow-gauge cars can be loaded below. These bins have a capacity

of 150 tons of coal and 200 tons of coke. The bins consumed about 150,000 feet of timber for construction.

A warehouse and long platform were constructed for the transfer of freight in car lots, the side tracks of the two roads being on opposite sides. A joint station building was provided for the transfer of passengers, baggage and express and the small lots of freight. Section house for trackmen was built at a convenient point. At Jerome there is an engine house and turn-table, and a two-story passenger and freight depot, with office in the second story. There are coal and coke bins, elevated, so that the fuel is delivered conveniently for use in the furnaces and power-house.

The machine shop and foundry used with smelting works furnish all necessary means for repairs, and usual work on engine and cars. This whole plant being so far from the centers where machinery and supplies can be procured, it has been necessary to have quite expensive shops.

There are water tanks, with 23,000 gallons capacity, at the ends of the line, and it is worth noting that an engine tank of water (2,000 gallons) taken at the junction will take a train to Jerome, doing eighteen miles of work.

Tracks are provided at the junction for the transfer of freight directly from car to car.

The road has two Baldwin compound Mogul engines, of which some of the features are: two cylinders, 10 inches in diameter; two cylinders of 17 inches; stroke, 20 inches; drivers, 41 inches diameter; driving wheel base, 9 feet; engine wheel base, 15 feet 5 inches; weight on drivers, 60,000 pounds; engine in working order, 70,000 pounds; capacity of tender, 2,000 gallons; weight of tender loaded, 36,000 pounds; train load, 120 tons behind the tender on 3 per cent. grade. There are fifteen flat cars, 24 feet long and 7 feet wide, with platform 3 feet 8 inches above the rail; some of these will probably be changed to coal cars; they were needed for construction work. There are ten coke cars, two box cars, and six coal cars, the latter with drop bottom and side gates, all of the same length, width and height as the flat cars, with 28-inch wheels. Freight cars have a capacity of 20,000 pounds. There is one combination coach 30 feet long and 8 feet wide. All cars have Westinghouse air brakes and Janney couplers. The couplers work nicely on the crooked road. All cars were purchased of the St. Charles Car Company.

An important item of the cost of the road is the freight charge on other roads on equipment, rails and lumber. It was found advisable to have home construction as far as practicable.

The following table gives some information concerning the bridges:

CLASS AND ALIGNMENT.	No. of Bridges.	No. of Spans.	Total Length.	Timber Ft. B. M.	Approximate Height.
Single Spans or Bulkheads . . .	3	3	38	7,442	4 to 7 ft.
Pile Bridges	5	75	1,050	138,416	5 to 8 ft.
Trestles on Tangents	4	40	581	123,259	25 to 48 ft.
Trestles on 16 Degree Curves . . .	2	16	218	33,940	20 and 25 ft.
Trestles on 24 Degree Curves . . .	2	22	325	64,973	27 and 40 ft.
Trestles on Curves 30, 34 and 36 Degrees	4	37	526	89,410	25 to 35 ft.
Trestles on 40 Degree Curves . . .	11	101	1,565	300,435	20 to 45 ft.
Trestles on 45 Degree Curves . . .	1	14	219	50,359	48 ft.
Trestles on Side Track	2	24	301	50,194	30 and 34 ft.
Totals	34	332	4,826	858,428	

The pile bridges, and one of the single spans, are in the valley, west of the mountains. It will be seen by the table that the gulches were all crossed at about the same height. It was thought to be advisable not to exceed fifty feet in height, for bridges crossing the gulches nor to lengthen the line by pushing up into narrow ravines, making a bridge less than thirty feet high. The gulches had to be crossed with curves, and places were selected by using a suitable curve which would keep the height of bridge within the limits. About one-half the places required 40° curves.

This bridge work covered one hundred days, with a gang of sixteen men and one team of horses. The work included framing and erecting, and practically amounted to 500 feet of timber per day to the man. A wire cable was stretched across the bridge opening at each place, and all the timber for the bents was lowered to place piece by piece and packed. The bents were then raised by using the cable. The deck was run out on dollies in the usual way.

The curvature on the line presents some interesting figures, which are shown in the following table:

Degree of Curves.	No. of Curves.	Angle, Right.	Angle, Left.	Total, Angle.	Length, Total.	In Feet, Average.
From 1 to 10 degrees	41	423° 23'	293° 30'	717° 18'	9284.8	226.4
" 11 " 20 "	59	1105° 15'	981° 17'	2086° 32'	13277.	225
" 21 " 30 "	44	1719° 49'	1127° 03'	2846° 52'	10531.5	239.5
" 31 " 40 "	42	1706° 11'	2414° 00'	4120° 11'	10521.4	250.5
" 45 "	1		162	162	360	
Totals	187	4955° 03'	4977° 50'	9932° 53'	43974.8	234

Total length of line covered by these curves 72,125 feet, or 13.66 miles.

Aggregate length of all curves 43,974.8 " or 8.33 "

" " " tangents 28,150 " or 5.33 "

Average " " curves 234 "

" " " tangents 166 "

Longest curve is 16°, or 960 feet.

Largest angle is in a thirty-degree curve, 162° 54'.

Longest tangent is 657.5 feet.

Average curve extending over entire line would be 13° 46'.

Average curve extending over curved portion of line would be 22° 35'.

Sixteen of the above curves are compounds, but the parts are taken separately in the lists of curves. Compounds are taken as single curves in giving average tangent. The amount of angle right or left differs only 22°. The numbers of curves in the different groups, as above taken, do not differ greatly. The greatest number of curves are found to be 13—10°, 16—12°, 16—20°, 13—24°, 23—30°, 34—40°.

The cost of the railway in working order, including equipment, can be approximately taken at \$12,000 per mile. As nine-tenths of the expense of grading and bridging occurred on the mountainous portion, the cost of this part comes to about \$15,000 per mile.

The various items of cost are shown by percentage as follows:

Grading	30.0	per cent.
Depot grounds (grading)	3.0	"
Bridge material	5.0	"
Bridge framing and erecting	3.0	"
Ties	5.0	"
Engineering expenses	3.3	"
Rails and fastenings	23.0	"
Track laying and surfacing	4.4	"
Handling all material	1.3	"
Construction train service	1.6	"
Buildings	3.4	"
Equipment	7.0	"
Freight paid other roads	10.0	"
	100.0	"

In estimating the expenses of managing and operating the road, the force required and the principal items of salaries, wages, etc., were taken as follows:

OFFICERS AND AGENTS.		PER DAY.
Superintendent, 1 clerk; auditor, 1 clerk; 2 agents	Salaries,	\$22 00
MAINTENANCE DEPARTMENT.		
Three foremen, bridge carpenter, 12 laborers	Wages,	25 00
TRAIN SERVICE.		
One crew		15 00
MACHINERY DEPARTMENT.		
Machinist, car repairers and supplies		12 00
Fuel—4 tons coal @ \$6.50 per ton		26 00
Total		\$100 00

It was expected that the superintendent would perform the duties of roadmaster, and that the bridge carpenter would obtain assistance from sectionmen and car repairers.

The laborers include those required for transferring at the junction. The smelter people were expected to load and unload cars at the works.

Machinists and car repairers would be under the direction of the superintendent of machinery at the works.

With a traffic of 120 tons per day, which will be about the average for the next two years, the cost per ton is 0.833. Interest charge on outlay for construction, \$18,600. Interest charge per ton, 0.425. Total cost per ton, \$1.258, or, approximately, 5 cents per ton per mile. This is rather a startling figure compared with rates at which the trunk lines of the country are doing business.

The line was completed and regular train service was put in operation the first day of December, 1894.

RIPARIAN OWNERSHIP OF LANDS BORDERING ON LAKES AND RIVERS.

BY J. H. ARMSTRONG, MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read December 3, 1894.]

THE following paper treats of the method of establishing the side lines of riparian lot-owners over the beds of lakes and rivers.

We may take, as a basis, the proposition that all lots bounded by tide waters take to high-water mark, while lots bounded by the great lakes and navigable rivers, take to the low-water mark. In both cases they are entitled to all accretions and relictions. Lots bounded by non-navigable lakes and rivers take to the center of the stream, and include all islands not otherwise disposed of by the Government.

The method of establishing the lines from the point where the Government survey ends is the principal subject of this paper. Of course, when an agreement cannot be arranged between property owners, the question has to be decided by the courts, yet the surveyor is a very necessary factor in the case. To him it is given to make the surveys and to mark such subdivisions as his judgment dictates, estimating quantities and preparing the engineering part of the case for the Court. The Court, not being a surveyor, takes the plans and evidence at hand and decides accordingly. If the plans and evidence are faulty, the case may be decided contrary to its real merits; consequently the surveyor should be fairly well posted in the decisions of former cases or his clients may suffer.

We will now take up the matter of lots bounded by rivers.



FIG. 1.

Fig. 1 will illustrate the point to which I wish to call your attention, viz.: the subdivision of the river bed and the extension of the side lines over those islands under the common law. I have shown here a portion of the Mississippi River, with several small islands.

Just south of lot 3, section 6, you will see a small island. You would naturally suppose that that

piece of land belonged to the owner of lot 3; yet, should the deep water channel be north of that island, no matter if only 100 feet wide, the title to that island and to the one in the center of the river goes to the owner

of lot 8. Now, the common law is supposed to dispense common justice to all, yet I see but little of the latter article in the provision of the law in this case. The old Roman law, by Gaius, states that if an island rises in the middle of a river, title to it is divided between the property owners on each side; if on one side, it goes to the nearest property owner. This looks more like justice.

Of what use is the deep-water channel to the owner of lot No. 8? To reach it he would have to wade through one-half mile of water from one to two feet deep. He would not be allowed to construct, for shipping purposes, a dock running out to that point. He is entitled simply to one-half of the last drop of water in the river, and this title is a phase of the question that will give us but little trouble. Navigable rivers are not in the habit of going dry. We may have low water for a few weeks in each year, but the stream may be full to the banks for the balance.

To illustrate the situation, we will suppose that the owner of lot 8 takes possession of those islands and improves them. They may be very valuable. Then a gradual change of channel takes place, the river cutting away the south bank until lot 8 entirely disappears. Of course, the owners of lots 2 and 3 would extend their lines to the south. In fact, I know of no limit to the extension, for the law provides that owners of lots bounded by rivers, being subject to loss, are not to be held accountable for their gains. (See *Jefferies vs. The East Omaha Land Company*.) You can see at a glance that fixing the boundaries in that neighborhood would be attended with some difficulty.

Then we will take lots 2 and 3, section 5, and suppose that a large amount of land has formed along their frontage. How are we to correctly divide these accretions amongst the lot-owners? The land thus formed is sometimes of great value, and, as the case often arises, the matter is worthy of your careful attention.

Prof. Johnson, in his excellent work on surveying, gives, as a rule, that we start at the original meander line and run to the center of the river, as nearly as possible at right angles with the general course of the same. This seems to be somewhat in conflict with the instructions of the General Land Office and the laws adopted by Congress in 1805, which direct that "the lines of fractional sections shall be established by running from established corners due north and south or east and west to the water course, Indian Reservation or other external boundaries of such fractional sections." . . . As an illustration, we will take the case of *Jefferies vs. the East Omaha Land Co.* (Supreme Ct. Reps., Vol. 10, p. 519). The case was tried in the United States Circuit Court before Judge Brewer, and in summing up he quotes the statute of 1805, directing that the lines be run due north and south or east and west, and decides as follows:

"These views result in the conclusion that the side lines of Lot 4 are to be extended to the river—not as the river ran at the time of the survey in 1851, but as it ran at the time of the patent in 1855, and that all land which existed at the latter date between the side lines so extended and between the line of the lot on the south and the river on the north was conveyed by the patent."

The case was carried to the United States Supreme Court, and the decree of the Circuit Court was sustained.

I consider this case of great importance, sustaining the point which I make, that the lines should be extended to the bank of the river and then deflected, the common law continuing the survey from that point.

The west line of the lot in question was the west line of Section 21, Township 75 N., Range 44 W.; and the lot was bounded on the north by the Missouri River. It originally contained 37.24 acres, and the accretions amounted to 40 acres more, the side lines being extended north about 1,320 feet. The first course of the original meander line, starting at the west line of Section 21, was S. 71° east. Should you start at the original meander corner and run a line at right angles with the river a distance of 1,320 feet, you would be about 450 feet east of where the line is now placed, a difference entirely too great to be lightly considered. It stands to reason, that the water course means the bank of the river; that is to say, no attention would be paid to overflowed meadow lands, nor would the lines be extended over a portion of the river bed on account of low water. I am aware that by producing the lines to the river bank, lot-owners may sometimes lose a water frontage; but with that the surveyor has nothing to do. He is making a survey under the instructions of the United States Government; and if these instructions mean anything, they mean that the lines shall be extended due north and south or east and west. It may be said that the lot, as bought by the owner from the Government, had a frontage on the river, according to the official survey; but it must be remembered, also, that he bought that piece of land under the laws adopted by Congress in 1796 and 1805, which give full directions how those lines shall be established. Any land-owner can plat his land, and give full instructions how the lot lines are to be extended over a pond on his land or the accretions along a river front; and if those instructions are plain enough, no law can change them. City lots, bounded by a pond, would be deflected at the point where the water line originally cut the lot line, unless a clause in the original plat directed otherwise. It seems to be no more unjust that a lot-owner should lose a small water frontage, for which he receives what is sometimes a valuable addition to his land, than that another should lose his entire lot, for which he receives nothing, while his neighbors on the opposite side of the river gradually extend their lines over and take possession.

Now the establishment of the side lines from the bank to the center of the river must be done under the common law. Where no lines have been established by the Court, I would give as a rule, that the first lot line on each side of the place where the work is to be done, that strikes the river practically at right angles, be selected and produced straight to the center line of the river; then measure the distance along the river bank, running straight from the intersection of the lot lines with the river bank, between the two lot lines first named; then ascertain the entire distance along the center line of the river between the two lines so extended, and give each lot-owner a distance on the center line equal to his frontage, plus or minus his apportionate share of the difference between the two lines. This method is practically what is known as the Massachusetts rule, and is certainly a very equitable one. I have given an illustration of this rule in Fig. 1, where the lot lines on the south side of the river are so extended. The center line I have shown on the diagram is a line midway between the original meander lines; but the rule will apply as well for the center of the channel.

In concluding the discussion on lots bounded by rivers, I will say that I see no reason why the general government, when issuing the original patent, should not limit the riparian rights of the lots to a line midway between the original meander lines. That would give us a good basis for future surveys, and would avoid the confusion which nearly always arises over the ever-changing channel.

We will now turn our attention to the subdivision of lake beds amongst the riparian owners. That is, perhaps, the most difficult problem the surveyor has to contend with. As I have before stated, the accretions and relictions belong to the riparian owners. By accretions, I mean the amount added to the land by the action of water washing up material; by relictions, lands uncovered by the change of channels in rivers or by the recession of water in lakes. All cases carried to the Supreme Court have been so decided. However, some doubts about the matter must have existed at Washington, for the Land Department, as late as 1877, would, on application, cause to be surveyed and disposed of as other public lands, reclaimed lake beds which had already been meandered and the adjoining lots disposed of. That certainly was in opposition to the common law governing such cases, for the Supreme Court says that when a patent is issued for land bounded by lake or stream, the title to the land under the water passes from the Government. See *Harden vs. Jordan*, Supreme Court Rep., Vol. 11, page 808 (1891). Chief Justice Miller, in *Moore vs. Robbins*, says: . . . "with the title passes away all authority or control of the Executive Department;" and again, referring to the power of the Secretary of the Interior, "after the patent, he is absolutely without authority."

Then, the riparian owner taking to the center of the lake, and there being no restrictions in the original patent, we have to subdivide the lake bed under the common law, which takes effect where the Government survey ends.

The lake shown in Fig. 2 is situated in West St. Paul. It was meandered in the original survey in 1853, and adjoining lots were sold.

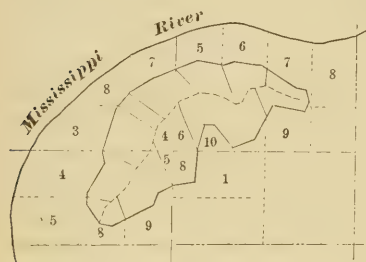


FIG. 2.

In 1861 the bed of the lake was subdivided by the Government and disposed of as public land. Litigation over the ownership in the bed of the lake commenced in 1872 between the riparian owners, the State, claiming under the swamp-land grant, and different railroad companies, and was finally settled in 1894 in favor of the riparian owners. So the case was before

the courts, in one shape or another, for a period of twenty-two years. You can imagine the costs. Then came an action for partition amongst the riparian owners of the lake bed, and it was subdivided under what is known as the Massachusetts rule, which I fully illustrate in Fig. 2.

I do not consider the above as a fair test of the rule, it being more of an agreement amongst the property owners than a trial on its merits. However, it is the most equitable rule yet advanced for a subdivision of lake beds, and I have no doubt it will be sustained by the higher courts, I understand that the rule will be further tested in a case to be tried soon. It will be watched with interest. The method of subdivision under that rule is as follows:

The center line is established by running midway between the original meander lines from the northwest to the southeast end of the lake. The distance is then measured on the northeast side, commencing at the intersection of the center line with the meander line and running straight to the intersection of the west line of lot 4 with the meander line, then running straight to the intersection of east line of lot 4 with the meander line, and so on to the intersection of the center line with the meander line at the southeast end of the lake. Then the distance is measured on the center line, and each lot-owner receives, on the center line, a distance equal to his frontage, plus or minus his proportion of the difference between the two lines. The southwest side is subdivided in the same manner. It is hardly necessary to state that it would be impossible to establish the center of the lake by attempting to use the water lines, for a boundary established in that way during the high water would probably differ all the way from 100 to 1,000 feet from

one established during low water, and according to that method both surveyors would be right.

In Fig. 3 I have shown four lakes meandered by the Government surveyors in their original surveys. They are now dry and fit for agricultural purposes. They are a fair specimen of the many to be found in this State. Lake "A," being long and irregular, is subdivided according to the Massachusetts rule. Lake "B," being nearly round, the side lines are drawn to a common center; that being the only way in which to apportion the bed of a round lake among the different lot-owners. The side lines around lake "C" are drawn to a common center. On lake "D" the Massachu-



FIG. 3.

setts rule is used. This figure is made to illustrate the method of subdivision, and although but little care has been taken in the make-up, I doubt if a court decision would materially change the side lines. Imagine each lot-owner having his portion of the lakes surveyed and fenced. Lake "B" would look like a clumsily constructed cart-wheel. Of course, in many cases two or three lots might belong to one owner, and this would improve the appearance of the picture; but it is quite possible that each lot is owned by different parties; in which case, under the riparian laws, their lines would be substantially as shown on the diagram.

Now, as to the amount of the lake beds received by each owner. Lot 4 in section 9, containing 3.3 acres, received 29 acres in lake "B" and 19.3 acres in lake "A," section 8; and lot 4 in section 16, containing 18.4 acres, receives 48 acres in lake "B" and 34.4 acres in lake "A"; lot 3, section 16, containing $7\frac{1}{2}$ acres, receives 38 acres in lake "B" and 20 acres in lake "C"; lot 10, section 8, containing 33.3 acres, receives 44 acres in lake "A" and 42 acres in lake "B." A party buying lot 4 in section 16, lot 4 in section 9 and lot 10 in section 8, would have to pay for 55 acres of land, and would receive as his share 217 acres of the lake beds—not a bad investment.

Of course the subdivision of the small lakes, around which the land has already been surveyed and disposed of by the general government, must come under the common law and the decisions of the court, or by agreement amongst the different lot-owners; but, going on the principle

that it is never too late to mend, why not have inserted in all future patents a clause which would permit the riparian owner of a fractional lot bounded by an unnavigable lake to take only so much of the lake bed as is required to fill out the lot of which he holds the fraction? For example, lot 4, section 9, would receive 40 acres in lake "B" and so on, the balance of the lake bed going to the State as school lands or for other purposes. In this way the rectangular system of surveys would be preserved, and when the fractional lot passed from the Government, its boundaries would be fixed for all time. Of course, when I say a full 40 acres, I mean plus or minus their proportion of the shortage or surplus in the section; very few sections containing exactly 640 acres.

I am aware I have given but little information in this paper, and that little perhaps not of the best, yet if I can get the matter generally discussed, a better understanding will be arrived at and my object attained.

THE STATE TOPOGRAPHICAL SURVEY OF MINNESOTA.

BY W. R. HOAG, STATE TOPOGRAPHER, PROFESSOR OF CIVIL ENGINEERING
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CLUB OF MINNEAPOLIS.

[Read November 19, 1894.*]

AMONG the needs of the people, those which are thought to fall to the Government or to the State for supply are, as a rule, slow in receiving just recognition. Whenever this tardiness becomes sufficiently pronounced, private capital steps in and often supplies the need, much more quickly and fully than public sentiment would have justified Congress or legislatures in doing. Tradition is strong, and we are slow to delegate to the Nation or to the State the control of those institutions which are now serving the people acceptably. Especially is this true of those which have had their birth and their doubtful beginnings since the establishment of our government. The railroad, the telegraph, the telephone and the express service might be named as examples in point.

There can be no doubt that the present great activity in the world of thought and of letters is directly due to the maintenance of our postal system upon the present plan, which imposes upon those employing it a tax too small to pay for the actual service rendered, to say nothing of a good profit such as must obtain if the work were to be long continued as a private enterprise, and which thus, in order to lighten the load of those who use it largely, imposes upon those who employ it but little, a tax disproportionate with the accommodation furnished them. The propriety of this arrangement is a legitimate topic of discussion for the political economist, yet all are agreed as to the great benefits conferred by the system as it is.

Who shall say what we, as a nation, have lost in activity and in consequent development by permitting our telegraph system to remain under private control, with rates and conditions in no way calculated to encourage its further adoption and as a rule prohibitory except where cost counts for naught or where the time element is a ruling consideration. The great question of transportation; not that much mooted question whether the Government should now acquire control of the rail and water ways of the country, but whether our territory would not have been developed much more rapidly and whether the strengthening and enriching effects of an efficient and economical system of transportation would not be present in a much larger measure than they are to-day had the Government from the first developed railroad transportation as it has developed the postal system.

* Manuscript received December 31, 1894.—*Secretary, Ass'n Eng. Soc.*

There is another class of needs which a civilized community soon comes to feel, but which, being of a more general nature than those already noted, has received but tardy recognition, especially in this country where the national government has taken up the work only after urgent specific needs have demanded consideration. I refer to the need of surveys of the public domain, whether conducted in order to discover the resources of the country as a purely geological and natural history survey, or as a topographical survey in order to meet the multifarious needs of our modern civilization.

Even the need of some scientifically consistent plan of description and partition of the land thrown open to settlement did not move Congress till a large amount of such lands had been disposed of and in a manner giving the most absurd and expensive plan for farm boundaries and unduly increasing the cost and uncertainty of all subsequent land surveys and descriptions. When finally the rectangular system of our public land surveys was devised and adopted, about 1810, the standard of desirable accuracy was placed so low, the execution of it by inexperienced contractors was so lamentably poor, and the government inspection of it was in many cases so farcical, that the resulting additional cost to the people from litigation has been estimated as already far exceeding what would have been necessary to make an absolute topographic survey in which every important subdivision line would be given exact position by a system of triangulation and traverse all having ultimate control in a rigid system of geodetic triangulation.

In 1790 it was seen that there was needed an exact knowledge of our coast line, both for developing and protecting the shipping interests and for purposes of public defense, and to meet this need the U. S. Coast Survey was organized. It began this great work in 1807. In 1841 the Lake Survey was organized for the definite purpose of making a geodetic survey of our shore line on the Great Lakes. In 1878 the Geological Survey was given the special work of conducting geological researches in the western territories, and it has since extended its field to the whole country. More recently it has confined itself principally to topographical surveys, in the absence of which it found itself unable to prosecute with satisfaction its geological studies. The coast lines, except those of Alaska, having been about completed in 1870, the work of the Coast Survey was enlarged by Act of Congress in 1871 so as to include hydrographic and topographic work on the great rivers of the country except the Mississippi and Missouri rivers, which had been assigned to special commissions in charge of the Army and Navy.

The Coast Survey, with the broadened title of Coast and Geodetic Survey, was also instructed to conduct a grand system of transcontinental triangulation and precise levels, not only for purely scientific purposes,

but also in order to co-ordinate its own work and that of any other agency. The exercise of this latter function was expected to aid especially in fixing international and interstate boundaries and thus to encourage State work of similar character. To still further aid each State in prosecuting its topographic survey, the U. S. Coast and Geodetic Survey was authorized to conduct a separate triangulation as a basis for such surveys in those States which had shown sufficient appreciation of the value of such by having put in vigorous operation their own State geological surveys.

To the U. S. Coast and Geodetic Survey was also entrusted the work of conducting a magnetic survey of the country.

And so, as special needs have arisen, they have been supplied either by a special agency or by giving the work given to some agency already established, to whose work that in hand was most closely related.

Congress has not seen fit to create an institution whose prime function shall be to make a complete and accurate topographic map of our whole territory. Nor is it likely to do so, for it has already created a number of distinct surveys, more or less national in character; one of whose functions is to make such a survey of its immediate locality, and the avowed purpose of one of the lines of work of its oldest survey—the Coast and Geodetic—is to assist the different States in carrying on their own surveys.

A further reason why the plan of individual State surveys is likely to prevail is the pride felt by each State in discovering and developing its own resources and in building up its own state institutions. In fact, each State desires that the needs of its citizens may be supplied as far as possible within the State and from its own resources.

Another difficulty in the way of inaugurating a general plan covering the whole country, appears when we consider that, on account of local difficulties, coupled with the desirability of great accuracy and full detail, the accurate mapping of some sections of the country might cost from two to five times as much as that of others.

Again, some States, from a keen appreciation of the economic worth of a reliable topographic map, would desire much more detailed and more expensive work than could be carried out in other States on any generally equitable plan. Just this has already happened in Massachusetts, where the National Geological Survey proposed to conduct the State topographical survey if the State would meet half the expense. In arranging the details of the contract, it appeared that the Geological Survey desired to do the work according to the plan which it usually followed elsewhere under like topographic conditions; but the State commission objected to this plan, claiming that the State could not afford to meet even half the expense of such a survey, which would produce a map but little better than the one already in existence.

In other States, by reason of general inactivity in all matters relating to public improvement, even a map of average cost would satisfy no present need, and all money so expended would become lost to the country until the State should awake to an appreciation of its true worth. On the other hand, it would be a manifest injustice not to carry the work along about equally in the different States.

Another evil which must attend the operation of such a plan is the following: Any national survey must have at its head a director or superintendent with power to direct the details of the work; the general policy alone could be fixed by Congress. The Survey, dependent upon the continued favorable action of Congress for maintenance, will, if it be loyal to its own cause, endeavor to merit and to gain the support of a majority in Congress. But congressmen, as a rule, are keen to see that their own States receive their full share of the benefits from such legislation. A system of political trading results, and friendly relations are maintained by doing work in some States and giving promises in others, sufficient to control a safe majority in Congress. The operation of such a system must result in a shifting policy, with a discontinuation of the work in some States in order to resume operations in others, following closely and actively every change in the political color of Congress. And thus a great agency, created to serve the best interests of the people impartially in a specific work, must soon degenerate into a vast political machine, an incidental feature of which is to do topographical work, while its main function is to serve Congress. While this picture may to some seem overdrawn, I firmly believe that, in view of the difficulties present, some of which I have specified above, any such survey would arrive at substantially this condition even before it could become efficiently operative.

Indeed, our country has already furnished proof of this certain tendency, and the development has progressed sufficiently to enable one familiar with the *modus operandi* of our national surveys to see the analogy. This difficulty can easily be avoided by allowing each State to take up its own work at the time and in the manner which seem to it best, conserving equally all the interests of the State and allowing it to receive from the general government whatever aid it may without sacrificing its control of its own work.

Although many States are at present engaged in conducting topographic surveys, according to one plan or another, only three—Massachusetts, Connecticut and New Jersey—have completed such surveys. In fact, we are far behind other nations in the appreciation of the economic value, to a State, of possessing, comparatively early, an accurate topographical map of its territory. As a natural result, we find that few States have taken advantage of the valuable co-operation

offered by the U. S. Coast and Geodetic Survey in furnishing free to the State for its topographic survey a triangulation which, as a foundation, must precede all topographic work proper, Minnesota being the ninth in the list thus co-operating.

The mining engineer fully realizes the value of a reliable topographic map of that section which is to be the field of his professional labor.

The municipal engineer knows that only by the aid of an accurate topographic map can he with certainty discuss questions relating to sources of water supply or to the location of reservoirs and standpipes, or trace out lines of natural drainage for use in designing systems of sewage disposal.

To the sanitary engineer such a map becomes a valuable aid in searching out sources of contamination in wells or in surface supply.

The geologist requires the aid of the topographic map for the fullest exposition of his results, especially in problems touching physical, stratigraphical and glacial geology.

The hydraulic engineer would need little else in determining the site and value of mill privileges, or in studying the overflow of land adjacent thereto.

The survey is of great value in prosecuting studies in natural history and meteorology, while to the civil engineer an adequate topographic map is the foundation upon which nearly all his problems must rest.

It has been estimated that Massachusetts alone has paid since 1836 \$20,000,000 in railway expenditures over what would have been necessary had it possessed at that time accurate topographic maps of its territory.

The army engineer can increase in a large measure the efficiency of the army by supplying it with topographic maps, enabling it to take advantage of every important feature which a map would clearly show. Our late civil war was undoubtedly prolonged not a little by reason of the superior knowledge possessed by the Southern generals, gained mostly by hastily prepared maps of their own territory, made immediately before and during the war.

To the agricultural districts the topographic map proves of the greatest value. It would aid the establishment and maintenance of a scientific system of highways, which to-day imposes the severest tax the farmer pays. It would give a uniform and absolute means of referencing land lines and corners, and data for settling all questions of land drainage or irrigation.

If further proof is desired showing that the people appreciate the need of better maps of our territory than those furnished by the original

land surveys, made half a century ago, it appears in the fact that private concerns have prepared such maps and have found for them among the people sufficient sale to justify the undertaking. The more settled portions of our State have already been twice surveyed and mapped in this way, and certain sections much oftener.

The foregoing are named as among the leading benefits to be derived from a reliable topographic map, and are offered only as part of those in which the survey would furnish the means for an economic solution of important questions. For every public improvement, while serving the immediate purpose for which it was made, goes further and creates new industries which in turn make new demands upon it. Engineers fully appreciate this, for where a public survey is lacking, they must either supply the deficiency by a special survey, or reach a doubtful conclusion from an imperfect co-ordination of the known factors.

Legislatures are apt to be slow in arriving at a full appreciation of the situation, and to favor moving very slowly at first, which I believe to be wise considering the permanent character of the work and the desirability that the triangulation, which is the foundation, shall be adequate to meet any demands likely to be put upon it, and considering also how few are professionally prepared to conduct such work.

A cheap and hastily prepared map is of little value. It serves chiefly as an object lesson, teaching the people by contrast the worth of a true topographic map. The rejection of maps based upon old surveys in favor of those of higher accuracy and greater detail has been the history of topographic surveys up to the middle of the present century. Many of the European States have thus covered their territory with repeated surveys.

Shall our State acquire an adequate topographic map by this costly method of development and repetition, or shall we, by adopting the modern practice of the science, prove that we do not need these costly lessons and begin our work upon the plan now universally adopted by every country on the globe at present conducting a topographic survey? This question received its first answer in the State legislature of 1872, which committed us to the policy of conducting our own topographic survey, to be based upon such actual surveys and measurements as may be necessary to produce an accurate map of the State.

This was the provision made in Section 5 of the act creating the Geological and Natural History Survey, which was drafted by W. W. Folwell, President of the University, introduced in the legislature by Senator J. S. Pillsbury, a regent of the University, and approved by Governor Horace Austin, March 1, 1872.

A second answer to this question was given in 1887, at which time, upon recommendation of N. H. Winchell, State Geologist, the writer

was appointed, by the Superintendent of the Coast and Geodetic Survey, Acting Assistant, and given immediate charge of its operations in this State.

The object of having these acting assistants appointed by the Superintendent of the U. S. Coast and Geodetic Survey, was to bring that part of the work requiring the most expensive instruments and the most rigid field methods and office reductions under the direct supervision of one central, highly professional authority. This alone insures that uniformity necessary where each State survey is to form, besides the unit in the State survey, an integral part of the one continental survey. It saves to each State the expense of providing costly instruments, needed only at stated times during the progress of the survey, as well as instruments for conducting the primary triangulation, vertical measures, leveling and magnetics. The general direction and care of the field-work is in the hands of officers of lifelong experience, and the reduction of the notes is made by professional computers at Washington. This assures that degree of accuracy which is essential to the objects of the survey; while, at the same time, local interests are conserved by the fact that the actual field-work is executed by citizens of the State, all the expenses of the work being borne by the National Survey.

Work was begun early in June, 1887, and it has continued almost uninterruptedly during the summer months, which were rendered available to the writer by freedom from other University duties, and which, at the same time, were most suitable for carrying on the field-work. During this time, astronomical latitude and azimuth and telegraphic longitude have been established at a station in the University grounds to serve as the absolute starting point of the survey. A primary base-line five and a half miles in length has been prepared and measured, located along Snelling Avenue, St. Paul, which furnishes the element of distance to all lines. A line of precise levels has been run from the nearest sea elevation bench mark to this base-line, thus giving it sea elevation. From this base-line, with its direction, latitude, longitude and sea elevation accurately known, a complete system of triangulation has been extended over the greater part of Hennepin, Ramsay, Washington, Dakota, Goodhue, Wabash and Winona counties, fully preparing this territory of about 2,500 square miles for the topographic work proper. Besides this important work, a reconnoissance looking to a plan of triangulation has been done in Chicago, Anoka, Wright, Carver, Scott, Rice, Dodge and Olmstead counties. For the past two years observations of magnetic declination have been made at all the stations occupied, with the view to making, at an early date, a complete magnetic map of the State for the use of all county surveyors. During the past season, employing

instruments loaned by the Coast and Geodetic Survey, the Civil Engineering Department has been conducting systematic observations at a magnetic station located at the experimental farm, for the purpose of studying the laws of change in the magnetic elements and preparing for the issuing of the magnetic charts. The past season has been spent in work upon a topographic sheet covering the twin city district, about 225 square miles. The first part of the season was devoted to the planetable triangulation, and the latter part to filling in the topography. Most of the latter work was confined to the interurban district west of Snelling Avenue, and to that extending along the Mississippi River and lake and park regions of the cities where the city records do not furnish adequate details.

The Superintendent has ruled that during the progress of the field-work of triangulation, in addition to locating the primary stations, which are 15 to 25 miles apart, the Acting Assistants shall be allowed to locate other objects, such as church spires, tall chimneys, towers, etc., for use as secondary stations for the State Topographic Survey when such location can be made without extra cost to the National Survey.

Since economy, as well as accuracy, demands that the primary stations be located in most cases as far from each other as possible, it is of the greatest importance that these secondary points—in sufficient number and in favorable positions—be chosen and located during the progress of the primary work. Especially is this true when tall observing towers must be erected at the primary stations in order to overlook surrounding woods or intervening ridges, for such towers are not likely to remain in position till they are needed by the State in its topographical survey.

In such a case the secondary and tertiary stations could not be located except by rebuilding the original towers, incurring an expense and delay in the topographical survey which the State could ill afford.

During the progress of the work in Hennepin, Ramsey, Washington and Dakota counties, but three towers were required, and a sufficient number of church spires, wind-mill towers, etc., were located as secondary points.

Quite the opposite conditions are met in Goodhue, Wabash and Winona counties. Here towers ranging in height from 24 feet to 64 feet, are required at nearly all stations, and owing to the small number of objects sighted but few secondary points could be established except wind-mill towers, which, from their great number and similarity, proved of very little value since all attempts at identification proved futile. This latter difficulty, which threatened to seriously impair the usefulness of the main triangulation to the State topographical survey, led the regents of the University of Minnesota, in the spring of 1892, to the

appointment of the writer as State Topographer, with instructions to make what observations were needed and to establish such secondary stations as would render the present work of the State triangulation of the greatest possible use to the State Topographical Survey.

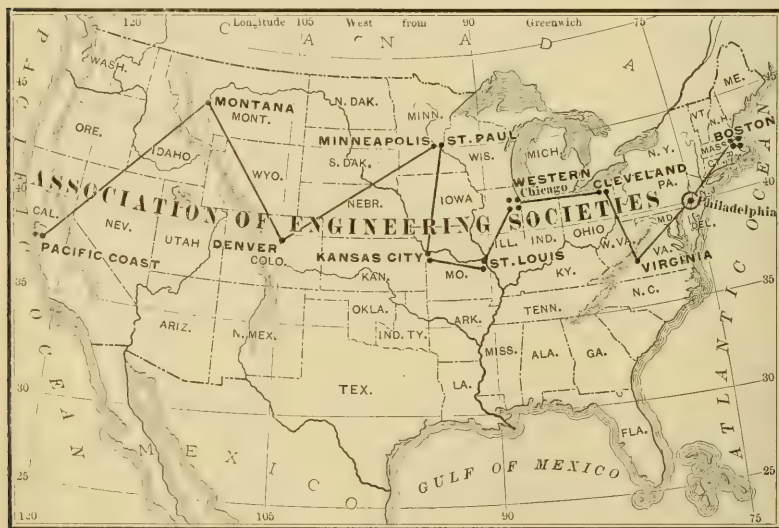
A topographical survey, such as is contemplated by a State, is a survey based upon absolute geodetic points and conducted by actual measurements and observations, the methods and the degree of accuracy throughout being sufficient to permit the construction of a map capable of showing accurately all topographical features as to *distance*, *direction* and *elevation*; *i. e.*, to show accurately in position, shape, direction, character, elevation, etc., all lakes, rivers, hills, ridges and valleys; woodland, prairie or cultivated land; lines of cultivation; government lines and corners; all highways, railroads and canals; all buildings in the country, in villages and in cities; with contour lines which would show all lines of natural drainage, the grade or pitch of all roads, the descent of all rivers, etc. Besides these, together with many other details which would be represented on the map, the survey comprehends a published report, issued at convenient intervals during the progress of the work, which shall contain, besides the usual report on general progress of the work, expenditures and estimates, etc., a full account of all methods and a description of the instruments employed, and of the methods and results of the office reduction and computation. The principal purpose of the report is to show, more accurately than the map, the exact data gained by the field-work. Such accuracy is necessary for the proper continuance of the field-work and for various practical and scientific uses of the survey. The value of such a survey to the State need not be argued, for the history of the progress of topographical surveys in every civilized country on the globe is sufficient proof of it. The older and more advanced nations, as England, France, Germany and Spain, have been the leaders in the sciences of topography and geodesy, each devoting large sums of money to provide accurate and reliable maps of its territory.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

From Ocean to Ocean.

In the Contribution Box for December, 1894, we chronicled the decision of the Western Society of Engineers to continue its membership in the Association of Engineering Societies; in January, 1895, we welcomed to membership the Denver Society of Civil Engineers and the Association of Engineers of Virginia, and we now have the pleasure to report the application of the Technical Society of the Pacific Coast for membership in the Association.



Bradley & Pontes, Engr's. N.Y.

Upon the admission of this society, the union of American engineering societies, effected by the Association, will extend from the Atlantic to the Pacific, and will thus become longitudinally co-extensive with the union of American states.

With the Boston Society of Civil Engineers (one of the original four) upon the Atlantic, with the Technical Society of the Pacific Coast at San Francisco, and with societies in Virginia, at Cleveland, O., Chicago, Ill., St. Louis and Kansas City, Mo., St. Paul and Minneapolis, Minn., Denver, Colo., and Montana, the Association embraces 52 degrees of longitude and 10 of latitude, and its JOURNAL may be taken as fairly representative of the various phases of American engineering practice.

The Board of Managers of the Association consists of one representative from each society of one hundred members or less, with one additional representative for

each additional one hundred members, or fraction thereof over fifty. In the map given herewith, each society is represented by one dot for each of its representatives on the Board.

The aggregate membership of the associated societies is now nearly 1,500. There were published in 1894 nearly 1,000 pages of papers, proceedings and index to current technical literature, and the JOURNAL has now reached a circulation of about 2,000.

The advantages of the co-operation thus secured, in the economy effected and in the interchange of ideas afforded, are so manifest that it would seem inevitable that the system thus established should rapidly extend its scope by giving rise to the formation of new local and sectional societies which should profit by the means thus afforded for the publication of their papers and proceedings.

Articles of Association and Chairman's Report.

For convenience of reference, a number of copies of the form containing the Articles of Association and the Report of the Chairman of the Board of Managers, have been reprinted from the January JOURNAL, and they will be sent to members of the associated societies upon application.

Mutilated Plates.

It appears that, through carelessness at the bindery, the plate accompanying Mr. S. Bent Russell's paper on "Points of Interest in the Design and Construction of the New St. Louis Water Works," in the January JOURNAL, was sheared in trimming some of the copies of the JOURNAL.

The Secretary is prepared to furnish new plates to replace any thus mutilated.

The Western Society's Membership.—Correction.

The attention of the Secretary has just been called to an unintentional misstatement of the membership of the Western Society of Engineers in the table on page 111 of the January JOURNAL, where the numbers of pages per member, contributed by the various societies, are compared.

For the purpose of this comparison, the mailing list for December, 1894, was taken as indicating the membership of the societies, but it now appears that a number of members of the Western Society had been dropped from that list pending payment of dues, without, however, forfeiting their membership in the society.

Judging from the table given on page 105 of the same JOURNAL, the membership should have been stated at about 350, instead of 293. This would, of course, affect the figures in the second and fourth columns, but, as the comparison was given simply as a matter of general interest, it is perhaps not worth while to print a corrected table.

Engineers' Office Buildings.

Two years ago, when the question of improved quarters for the American Society of Civil Engineers was being discussed, the Collector ventured to suggest to

that society the wisdom of uniting with its sister societies, at least with those of the mechanical, mining and electrical persuasions, to erect a joint office building for the use of the several societies.

Such a building, it was felt, would give the societies vastly improved accommodations, would establish an engineering headquarters in New York City (inasmuch as engineers of all branches would surely find it to their interests to occupy offices in such a building) and, last but not least, would form a handsome source of revenue to the participating societies.

It will be seen that the proposition amounted simply to this: that the great national societies having headquarters in New York should unite for the purpose of securing a home, as our local and sectional societies have united in the Association of Engineering Societies for the purpose of publishing their proceedings.

Although, to all appearances, no steps have been taken in the direction suggested, the Collector believes that it is merely a matter of time when the societies will realize the advisability of such a step. Already we notice, as a straw indicating the direction of the wind, a movement on the part of engineers in Chicago toward something of the same sort of concentration as is here suggested.

The Western Society of Engineers has long been in want of better quarters than those previously occupied in the now antiquated Lakeside Building, and the Society, by acting in co-operation with a number of engineers who were similarly situated, and by taking a large amount of space in the Monadnock Block, were enabled to secure more favorable arrangements than could otherwise have been effected.

One of the engineers in question writes: "We are very comfortable in this building, which now contains, no doubt, more engineers and persons connected with engineering occupations than any other."

Progress of the Metric System.

The Box is informed that Congress has passed a bill providing for a commission to report upon the propriety of introducing the metric system of weights and measures into the United States. The commission consists of the Secretary of the Treasury, the Director of the Mint and the Superintendent of the Coast and Geodetic Survey—Messrs. John G. Carlisle, Robert E. Preston and William W. Duffield. It is expected that the report of the commission will be made to the Fifty-fourth Congress when it meets.

The adoption, by Act of Congress, of standard units of electrical measurement based on the metric system, has been completed by the report to Congress of the National Academy of Sciences, to which was intrusted the duty of prescribing specifications of details necessary for the practical application of the definitions of units.

In England, on February 13th, the House of Commons appointed a select committee to inquire whether any and what changes of their weights and measures is desirable. There is reason to hope for a report favorable to the metric system.

Timber Physics.

Thus far between thirty and forty thousand tests of timber have been made at the laboratory at Washington University, St. Louis, under the auspices of the Forestry Division of the Department of Agriculture.

As a result of these tests, a number of generally held opinions respecting timber have been reversed and others modified.

It has been shown, for instance, that seasoned lumber is about twice as strong as green lumber, but that well-seasoned lumber, if soaked in water or left for a time in a damp place, loses its strength with the absorption of moisture. On the other hand, when the moisture is diminished below 4 per cent., a slight decrease in strength begins to appear.

Again, it has been demonstrated that timbers of large section have equal strength per square inch with smaller ones, when they are equally free from blemish.

Another time-honored tradition which has been relegated to the lumber loft is that knots, while weakening a beam, do not affect the strength of a column. The tests at St. Louis have fully established the fact that a knot is as great a source of weakness in a column as in a beam.

That the tests in question have dissipated the venerable prejudice against bled timber is now well known.

Finally, the tests show that long leaf, or Georgia pine, is stronger than average oak.

In Alabama, along the Louisville and Nashville Road, a large amount of chestnut oak was felled a few weeks ago for the tanned bark alone, the wood being allowed to rot because its value for railroad ties was not known. The Division of Forestry, in a circular, called attention to the superiority of this timber for ties, and the wood is now utilized, effecting an annual saving, for that region alone, of from forty to fifty thousand dollars, or more than three or four times as much as the annual appropriations for the Division of Forestry.

Topographic Maps of the United States Geological Survey.

As a basis for its geologic representation, the U. S. Geological Survey is preparing, through actual survey, a series of topographic maps, which, when completed, will cover the entire United States. For convenience of designation, the maps, which are about 19 by 22 inches in size, are listed under a State series heading, and receive, as a sub-title, the name of the most important city within their limits, thus giving a suggestion of the locality covered.

So far, nearly 900 maps have been issued. They are prepared on a scale of 1:62,500 and cover one-sixteenth of a degree of the earth's surface. The physical features of the country are well represented, and the contour delineation, on a scale of 20-foot intervals, must make the maps valuable as an aid to engineering enterprises where an accurate knowledge of the country is indispensable. The political geography is well followed, and the various roads and railroads are given.

In the distribution of these sheets, the Director of the Survey has endeavored to place the maps in the possession of those who have actual need for them.

Application should be made, through a member of Congress, to the Director of the United States Geological Survey, Washington, D. C.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Rankine's Civil Engineering. NOTES ON —, after the Notes of Prof. William Allen and G. W. C. Lee; by Prof. David C. Humphreys, C. E., Washington and Lee University, Lexington, Va. 1894. 184 pages, 9 x 12 inches, autolithograph. Illustrated. Price \$4.00, post-paid.

A translation of Rankine's monumental works into the vernacular, such as would render their many obscure passages intelligible to engineers, has been a desideratum ever since their appearance. The author and his two predecessors have not attempted this, but have confined themselves to the task of elucidating those comparatively few portions which might be expected to present difficulties to students. Thus we find no explanation of the following passages on pages 673 and 674:

The Total Head of a given particle of water is found by adding together the following quantities:

The head of pressure, or intensity of the pressure exerted by the particle, expressed in feet of water.

The head of elevation, or actual height of the particle above some fixed or "datum" level.

In order to acquire velocity from a state of rest, or an increase of velocity, a fluid particle must pass from a place of greater total head to a place of less total head. This it may do either by actual descent from a higher to a lower level, or by passing from a place of more intense pressure to a place of less intense pressure, or by both those changes combined.

From this circumstance we judge that the student finds these passages as plain as day, without a diagram.

The author has devoted to his task a vast amount of intelligent labor, not only in the preparation of the text, but in that of the very numerous and excellent illustrations, which are far superior, in point of intelligibility, to those in Rankine's work itself.

The Notes were prepared primarily for use in the author's classes, but they will undoubtedly prove of great value to other students of Rankine.

Machine Design. NOTES ON —. By Prof. Charles H. BENJAMIN, Case School of Applied Science, Cleveland, Ohio. Pamphlet, 74 pages, 5 by 9 inches.

In the Library for May, 1894, we noticed the author's notes on Heat and Steam. The present volume is uniform with the preceding and similar in the scope of its purpose, which is, "to gather together in small compass the more simple formulas for the strength and stiffness of machine parts, with an explanation of the principles involved, and with such tables and information as the designer of machinery might find useful,—to put the mathematical principles of machine design in a compact form, at a moderate price, for the use of the student and the young engineer." The English system of weights and measures is adhered to, and

the book is interleaved with blank pages for the convenience of the student. The various propositions are fully and satisfactorily, although not very artistically, illustrated.

Elementary Principles of Mechanics. Vol. II. Statics. By A. Jay Du Bois, C. E., Ph.D., Professor of Civil Engineering in the Sheffield Scientific School of Yale University. First edition. First thousand. New York: John Wiley & Sons, 1894. Cloth, \$4.00. 392 pages.

In the Library for October we noticed the appearance of the first volume of this work, viz.: Kinematics, and the remarks there made apply with full force to this second volume of the series, not the least important feature of which is the very large number of examples by which the propositions are illustrated, and which are worked out in the text.

Aërial Navigation ; Proceedings of the International Congress of—, held in Chicago, August 1, 2, 3 and 4, 1893. *The American Engineer and Railroad Journal.* New York, 1894. 414 pages and Index. 5 $\frac{3}{4}$ x 8 $\frac{1}{2}$. Price \$2.50.

In the Library for July, 1894, we noticed, at considerable length, Mr. O. Chanute's monumental work upon Progress in Flying Machines. The present volume appears under the auspices of the same publishers, and, unfortunately, in the same fine and closely-set type.

This notable conference was opened by Mr. Chanute, Chairman of the Organizing Committee, who presided over the first day's session, at which the scientific principles of aërial navigation were discussed. The amount of material presented is so great that we can here barely allude to a few of the most notable papers, as follows:

On the Internal Work of the Wind. By Prof. S. P. Langley, Secretary of the Smithsonian Institute.

On Atmospheric Gusts and on Aëroplanes and Flying Machines. By Prof. A. F. Zahm.

On the Mechanics of Flight and Aspiration. By A. M. Wellington. (A paper discussed by Messrs. J. Bretonnière and H. A. Hazen.)

On a Theory of Sailing Flight, on Aëroplanes and Flapping Machines, and a Note on the Elastic Screw. By William Kress, of Vienna.

Flying Machines, Motors and Cellular Kites. By Lawrence Hargrave, the noted experimenter, of Sydney, New South Wales.

On Flotation *versus* Aviation. By Prof. DeVolson Wood.

On Systematic Explorations of the Upper Air, with Estimates of Cost. By Mark W. Harrington, Chief of Weather Bureau, Washington, D. C.

On Scientific Results Gained by Balloons, and Ten Miles Above the Earth. By H. A. Hazen, of the Weather Bureau.

Also four papers by Carl E. Myers, whose name is followed by the novel title of Aëronautical Engineer.

Prof. Thurston contributes Notes on the Materials of Aëronautic Engineering, and C. E. Duryea, of Peoria, Ill., one with the significant title "Learning How to Fly."

Les Réformes des Tarifs de Voyageurs. By L. de Perl, Counsellor of State, Director of International Service of Russian Railways. Published by order and under the auspices of the Russian Ministry of Finance. Paris: J. Rothschild. 1893. 279 pages.

The author's instructions from the Russian Minister of Finance contemplated the study of the reform of passenger tariffs adopted by the Hungarian Government,

with a view to ascertain its applicability to the Russian railways; but, in pursuing these studies, the author became convinced that an examination of the Hungarian system alone would not suffice for arriving at a proper view of the main question, and he has therefore extended his investigations to the systems in vogue in other European countries.

In the first chapter the author reviews the history of reform in passenger rates, beginning with the project of William Galt in England, in 1843, following close upon the reform of postal charges introduced by Rowland Hill in 1840, reforms which give to England the credit of pioneership in both directions.

The systems inaugurated in the several European countries are then examined and discussed in detail, and the author sums up his conclusions, in which he recommends the adoption of the differential tariff in preference to the Zone system, and proposes a tariff affecting material reductions in existing rates, the reductions increasing as the distance traveled increases.

U. S. Department of Agriculture,—Office of Road Inquiry. Bulletins 1-8.

No. 1 is a valuable compilation, by General Roy Stone, Special Agent in Charge of Road Inquiry, of State Laws relating to the management of roads, enacted from 1888 to 1893. Fourteen States are here represented, and the laws given are nearly all of the year 1893, although New Jersey, the pioneer State in the matter of new road laws, began enacting them as early as 1888.

No. 2, Proceedings of the Minnesota Good Roads Convention, held at St. Paul, Minn., January 25 and 26, 1894.

No. 3, The Improvement of the Road System of Georgia, by O. H. Sheffield, C. E., with an illustrated description of the methods employed.

No. 4 is a report on Road-Making Materials in Arkansas, by John C. Branner, State Geologist.

Nos. 5, 6 and 7 give Information regarding Road Materials and Transportation Rates in certain States west of the Mississippi River, north of the Ohio River, and in the eastern and southern sections, respectively.

No. 8, The Construction and Repair of Earth Roads, by General Stone.

No. 9, State Aid to Road-Building in New Jersey, by Edward Burrough, Chairman of the New Jersey State Board of Agriculture and State Commissioner of Public Roads.

Building for Library of Congress,—Report upon the Construction of the — during the year ending December 1, 1894.

The two photographic views here shown, one taken from the dome of the Capitol and the other from near the southwest corner of the Library building, both taken on November 20, 1894, show that the latter was at that time nearing completion. The last stone of the superstructure was laid on July 7th, and the last of the walls of the building proper was thus completed. At the date of the report, December 3d, operations were still actively progressing, some 400 workmen being steadily employed. It is confidently stated that in the event of sufficient appropriations the building will be finished early in 1897, and that the total cost will be within the limit fixed by law. Over four million dollars have already been expended. Mr. Bernard R. Green, C. E., Member American Society Civil Engineers, is in charge of the work.

The report contains a plan for a tunnel to connect the Library building with the Capitol. The tunnel will contain a cable for the rapid transmission of books,

etc., between the two buildings, and a small pneumatic tube for the transmission of written messages, telephone wires, etc. It is said that the cost of the tunnel and apparatus complete will not exceed \$35,000.

Washington Aqueduct; Annual Report upon the—, Increasing Water Supply of the City of Washington, and Erection of Fish Ways at the Great Falls of the Potomac, in charge of George H. Elliot, Colonel Corps Engineers, U. S. A. Washington, 1895.

In discussing the Washington aqueduct, Colonel Elliot takes up the subject of filtration of the city's water supply, and, after considering the claims of mechanical or rapid, and of natural or slow, filtration, he reaches the conclusion that there appears to be no cause for apprehension respecting the healthfulness of Potomac water as delivered by the river into the intake of the aqueduct at Great Falls; and that, as long as the present condition continues, the great expenditures that would be required for the first cost of filtration works and for the annual cost of their maintenance would not be justifiable, and that for the present, at least, reliance should be had on sedimentation.

California State Mining Bureau.—Twelfth Report of the State Mineralogist. Sacramento, 1894.

Although the act of the California Legislature providing for the establishment of the State Mining Bureau was not approved until March 23, 1893, the bureau has already shown marked activity, as witness the second biennial report of the State Mineralogist now before us. This constitutes a veritable mineralogical and geological description of the State, the principal products being treated in alphabetical order. Naturally gold monopolizes some 250 pages, or nearly one half of the entire volume, but structural materials, and notably granite and other building stones come in for extensive mention. The volume is handsomely illustrated by photographic and other views, some of which present remarkably striking scenic features. Mr. Thomas Haight Leggett contributes an elaborately illustrated paper of forty-one pages on the Use of Electric Power Transmission Plants in Mining Operations, and the report closes with geological notices of certain of the counties of the State, and an appendix containing various acts of legislature bearing upon the mineral industries of the State. In addition to the preparation of its reports, the bureau issues, from time to time, bulletins, one of which, by Mr. W. H. Storms, on Methods of Mine Timbering, was briefly noticed in the Library for August, 1894.

Society Proceedings.

AMERICAN SOCIETY OF CIVIL ENGINEERS, Transactions of the ——.

December, 1894, Vol. XXXII, No. 6.

The prominent feature of this number is an elaborate and handsomely illustrated paper by Mr. John Thomson, describing the Platen Process for Letter-Press Printing, etc. Mr. Bolton W. DeCourcy contributes an account of the Improvement of Gray's Harbor, Wash., and Prof. Mansfield Merriman discusses, in an illustrated paper, the Strength and Weathering Qualities of Roofing Slates.

FEDERATED INSTITUTION OF MINING ENGINEERS, Transactions of the ——. Vol. VIII, No. 1. Issued November 24, 1894. Newcastle-upon-Tyne. Price 12s.

In the Contribution Box for January, 1895, we gave a brief account of this Institution, which, like our own Association, secures co-operation among a number of engineering societies for the benefit of all.

We now receive from the Secretary a copy of these Transactions, which we may with profit compare with our own JOURNAL.

We note, in the first place, that the price of this one issue, with its 224 pages, is the same as our subscription price for our annual volume, which now contains about 1,000 pages of reading matter and index.

We note, further, that, notwithstanding the improvement which has been effected in the appearance of our JOURNAL, this British publication is still, in many respects, decidedly superior to our own, but we may trust that when our subscription rate has been quadrupled we may appear in as handsome shape.

As might be expected from the title of the Institution, the papers presented bear almost exclusively upon matters of interest to mining engineers, but Mr. Morgan W. Davies contributes a paper, illustrated by four plates, upon timber bridges and viaducts.

The gas tester for detecting and estimating fire-damp in mines, invented by Thomas Shaw, of Philadelphia, is described and illustrated by Mr. Joseph R. Wilson, member of the American Institute of Mining Engineers.



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THE CHICAGO SANITARY DISTRICT CANAL.

I. Introductory.

BY ISHAM RANDOLPH, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read August 1, 1894.*]

I APPEAR before you to-night in fulfillment of a promise made to our worthy Secretary some weeks ago, that I would prepare and present at this time a paper upon the work of the Sanitary District of Chicago which should be the introduction to a series of papers to be prepared by the Engineers directly in charge of the several Divisions, descriptive of the methods pursued and the results accomplished upon the sections under their direction. The promise was a rash one, and I now know that I should not have made it.

When a work of this magnitude is being crowded forward, it demands the entire time and the best thought of its executive head. This being true, I find that in making the promise to which I stand committed I have done myself an injustice no less than the enterprise of which I have undertaken to treat, besides the still further wrong of disappointing an audience which I would fain please, if I cannot instruct. With this introduction and apology, I will proceed at once to the subject in hand.

The Sanitary District of Chicago comprises practically all of the city north of 87th Street, and about forty-three square miles of Cook

* Manuscript received March 11, 1895.—*Secretary, Assn. Eng. Socs.*

County outside and west of the city limits. It would be interesting to introduce here a few pages of history ; to review the causes which, year by year, with the growth of this mighty city, have gathered force and unity until they have compelled action.

A review of the various projects proposed for relieving Chicago of its incubus of filth, and a presentation of the arguments put forward by the advocates of each project, would afford subject-matter both instructive and entertaining ; but it is not for me to take up the by-gones. The issues have been joined, and one of the theories of yesterday is passing rapidly to-day into the fact accomplished.

The Sanitary District of Chicago was organized under the law for incorporating Sanitary Districts, enacted by the Legislature of the State of Illinois in 1889, approved May 30th, and in force July 1st, 1889. It is entirely separate and distinct from the municipal government of Chicago. Under the general law above referred to, the Trustees may levy and collect taxes for carrying on the work intrusted to them, to the extent of one-half of one per cent. per annum of the value of the taxable property within the corporate limits of the District, as the same shall be assessed and equalized for State and County taxes of the year in which the levy is made. They may issue bonds to the extent of 5 per cent. of the value of the taxable property of the District, as determined by the last assessment for State and County taxes previous to the issue of said bonds ; provided, however, that said 5 per cent. shall not exceed the sum of \$15,000,000. The population of the District is now about 1,400,000, and the assessed value of the property is \$242,-438,000.

The District organization constitutes probably the most independent civil corporation extant. The Trustees, nine in number, are elected by the voters of the District, and hold office for a term of five years. They take their commissions from the people and are answerable to the people only. They elect one of their own number President, and the term of office is one year. The officers, other than Trustees, are a Clerk, Treasurer, Chief Engineer and Attorney, each with an appropriate staff of assistants.

The first Board of Trustees was elected November, 1889, and their first meeting for organization was on January 18, 1890, in Judge Drigg's Court Room, in the County Court House in this city. Trustees-elect John J. Altpeter, A. P. Gilmore, John A. King, Murray Nelson, Richard Pendergast, W. H. Russell, Frank Wenter and H. J. Willing were present, and Trustee-elect Christoph Hotz was absent. On that occasion a temporary organization was effected, which was followed by a perfected organization on February 15th of the same year, when the " Rules and Order of Business of the Board of Trustees " were adopted

and officers elected. The law which conferred their powers and responsibilities upon them, prescribed, in the following language, how they should construct the channel :

“If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Desplaines or Illinois River, such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than fourteen feet, and a current not exceeding three miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan of not less than eighteen feet, such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than one hundred and sixty feet at the bottom capable of producing a depth of not less than eighteen feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000, such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than three miles per hour, and if at any time the general government shall improve the Desplaines or Illinois Rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall within one year thereafter, enlarge the entire channel leading into said Desplaines or Illinois Rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute, with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom, in case a channel is constructed in the Desplaines River as contemplated in this section, it shall be carried down the slope between Lockport and Joliet, to the pool commonly known as the upper basin, of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act, may correct, modify and remove obstructions in the Des-

plaines and Illinois Rivers wherever it shall be necessary so to do to prevent overflow or damage along said river, and shall remove the dams at Henry and Copperas Creeks, in the Illinois River, before any water shall be turned into the said channel. And the Canal Commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers, by any drainage district or districts, to maintain a depth of not less than six feet from any dam owned by the State, to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dam, at low water, then it shall be the duty of said Canal Commissioners to cause such dam or dams to be removed. This act shall not be construed to authorize the injury or destruction of existing water-power rights.

“Control of channel when completed: When such channel shall be completed, and the water turned therein, to the amount of 300,000 cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the general government shall improve the Desplaines and Illinois Rivers for navigation, to connect with this channel, said general government shall have full control over the same for navigation puposes, but not to interfere with its control for sanitary or drainage purposes.”

The carrying out of these requirements being an engineering work, a Chief Engineer was elected at the first meeting of the Board after permanent organization had been effected, and his duties, as set forth in the rules, were as follows: “The Chief Engineer shall have charge of all engineering work and shall do all surveying and civil engineering necessary or ordered by the Board; make all plans, estimates, drawings, figures and reports required by the Board; and shall perform such other duties as may be imposed upon him from time to time by ordinances or resolutions of the Board.” On February 8th, Mr. L. E. Cooley, the Chief Engineer elect, reported to the board, “that all of the work preliminary to actual work of construction would require until the Spring of 1892.” For several months the Chief Engineer seems to have constituted the engineering department, for while he was authorized to “secure and have in readiness” “a sufficient staff to do all of the engineering work,” yet the decree recited further, “compensation of services not to commence until ordered by this board.” In explanation of this a quotation from the proceedings of February 1st, suffices: “Resolved, that the officers selected shall not be entitled to draw salaries until after the Supreme Court shall have affirmed the validity of the law.”

On June 14, 1890, at the eighteenth regular meeting, President Nelson called the meeting to order and spoke as follows: “Gentlemen, we now have the decision of the Supreme Court. There is nothing in the way to prevent our going ahead as rapidly as possible.” At this

meeting Mr. Wm. M. Reese was appointed Chief Assistant to the Chief Engineer, and Messrs. Thomas T. Johnston and Wm. T. Blunt Principal Assistants, and we may conclude that the active work of the engineering department dated from that time. You have heard that the course of true love never did run smooth, and the same assertion applies to the courses of the Chief Engineers of this District. With active work came active opposition to the Chief Executive of the Engineering Department, and, to quote his own description of the disaster on the 10th of December, 1890, he "was thrown down stairs." You have heard of the certain resurrection of truth crushed to earth. Well, the Chief Engineer, like truth, rose again and was bidden by the people to take a place among the trustees as the peer of those who had helped him down stairs on the memorable 10th of December. He was succeeded by Mr. W. E. Worthen, who was elected on December 17, 1890, and had associated with him, as consulting engineer, General John Newton. These gentlemen remained with the District until April 21, 1891, when they resigned. On May 9, 1891, Mr. Samuel G. Artingstall was elected Chief Engineer and he held the office until January 16, 1892. His successor, Mr. Benezette Williams, was elected on the day of his retirement. Mr. Williams' incumbency of the office lasted until June 8, 1893, and since that date I have had the honor of being Chief of the Department. So much for the chronology of office-holding. It is not in order now to discuss the various routes proposed for the Main Drainage Channel nor to review the arguments advanced in favor of each, as we are dealing with the channel upon the route finally adopted and made irrevocable by the purchase of a right of way costing nearly \$2,603,228, and the execution of contracts, covering 28 miles of construction, which are now being pushed forward with a rapidity unexcelled, if ever equalled, in the history of any engineering enterprise. This location is essentially parallel with the line of the Illinois and Michigan Canal. Although minor defects in alignment have been avoided, lighter curves used and longer tangents secured, the maximum curvature is $0^{\circ} 36'$. That portion of the route southwesterly from Willow Springs was first adopted and put under contract. The work was divided into sections averaging about one mile each, and these were numbered consecutively from 1 to 14, No. 1 commencing at the Willow Springs Road. It being considered that these were the most difficult sections, because eight of the fourteen were practically through rock cuts, and the other six were underlaid with solid rock which would form a large percentage of the entire volume, these sections were first advertised for contract, and the contracts were awarded in July, 1892. On September 3, 1892, which passed into the annals of the enterprise as "shovel day," the work was officially inaugurated in the presence of

a large company assembled on each side of the line between Cook and Will Counties, where it is crossed by the channel. President Frank Wenter wielded the official nickle-plated shovel which turned the first sod, and Trustee L. E. Cooley manipulated the battery which discharged the first blast. Speeches were made by officers of the District and by distinguished guests, and the great enterprise was fairly launched.

Easterly from Willow Springs Road, the sections are lettered from A to O, omitting J, and are entirely in "glacial drift" except for a few hundred feet on each side of the Summit Road, in sections E and F, where test-pits indicate rock rising about seven feet above the grade line at the highest point. The lettered sections are now all under contract. Sections A to F were awarded late in 1892 and early in 1893. G to M inclusive were awarded in December, 1893, and N and O in May, 1894. The cross-section finally adopted for all of the numbered sections, which will be partially or wholly in rock, is 160 feet wide at bottom and 162 feet wide at top. The sides in rock are cut vertically by channeling machines, and three stopes are prescribed, with off-sets of six inches for each stope to admit of using the channeler. The numbered sections, which are partially in earth and partially in rock, are to be walled above the rock to an elevation of 5 feet above Chicago Datum. To build these retaining walls on these sections, nearly 300,000 cubic yards of masonry will be required. The original specifications for this masonry contemplated dry rubble. The developements on the rock sections convinced me that rock to fit the specifications could not be had from the excavations, and I prevailed upon the Board to adopt cement masonry specifications. These specifications provide for the use of mortar made of cement and sand in equal parts.

The earth sections are to be 202 feet at bottom, with side slopes of 2 feet horizontal to 1 foot vertical. The earth sections, east of the range line near Summit, are not being excavated to full width. The bottom width of present excavation is only 102 feet, side slopes two to one. The reason for this is that the future enlargement can be economically made by dredging, and a present saving is effected by reducing the acreage necessary to be purchased for spoil area.

The grade throughout the lettered sections is 1 foot in 40,000 feet (0.025 per 100), and the bottom of the channel at Robey Street is 24.448 feet below datum. The grade in the numbered sections is 1 foot in 20,000 feet (0.05 per 1000).

The specifications under which this work has been contracted for, provide for but two classifications, Glacial Drift and Solid Rock. Glacial Drift is a drag net which catches everything but solid rock. The definition reads thus: "Glacial Drift shall comprise the top soil, earth,

muck, sand, gravel, clay, hard pan, boulders, fragmentary rock displaced from its original bed, and any other material that overlies the solid rock."

Solid Rock is defined in the following terms: "Solid Rock shall comprise all rock found in its original bed, even though it may be so loosened from the adjacent underlying rock that it can be removed without blasting."

The bids for Section No. 15 are to be opened on the 22d of August. This is the extreme southerly section of the channel, and on it will be located the controlling works. The design of these works is to control the discharge from the main channel into the tail race. When the flow is normal, the crest of the discharge over the waste weirs will be about eight feet below Chicago Datum, but, under conditions which may obtain, the flow will have to be shut off and the water held up to lake level, which may reach five (5) feet above datum. This section, as will be seen by an examination of the plat, fans out to a width of 505 feet. This peculiar shape does not accord with my personal views of what should be done on this section, and I am hopeful of being able, before the work progresses too far, to recast the plan upon lines which seem to me better suited to the conditions which must obtain. Our contracts provide for changes of plan during the progress of the work.

While Section No. 15 ends the Main Drainage Channel, it does not mark the southerly limit of work to be done by the Sanitary District. This work consists in preparing a tail race to receive the outflow from the channel, or practically a correction and enlargement of the Des plaines River Channel for a distance of about nine thousand feet, a work the estimated cost of which is \$425,260. In addition to this, quite a large amount of work has to be done in making the channel through the city of Joliet adequate to the passage of 600,000 cubic feet of water per minute, additional to the flow of the Desplaines proper; then, too, the removal of the dams in the Illinois River, at Henry and at Copperas Creek, is made obligatory under the law.

So far I have made no mention of a most important auxiliary work which was accomplished last season. I mean the diversion of the Desplaines River. For long distances the location of the main channel occupied the bed of the Desplaines, and almost its entire length was subject to inundation during flood seasons. It is readily understood, therefore, that plans for diverting this stream had to be carried to completion before the work on the main channel could be prosecuted successfully. This work came under the head of the River Diversion Channel. About 13 miles of new channel had to be excavated. The width of cross-section adopted was 200 feet. Levees had to be constructed from the high ground below Riverside through to Romeo, a

distance of about 19 miles. A small portion of this levee still remains unfinished, but this season will see a decree of complete divorce between the waters of the Desplaines and the Main Drainage Channel in the shape of permanent barriers. At the head of this diversion it was necessary to provide a safety valve in the shape of a spillway to allow surplus water to flow toward Chicago, because arrangements have not been perfected for carrying the entire flood waters of the Desplaines through Joliet. This spillway is a concrete dam capped with cut stone, and its wings are faced with stone masonry. It is 397 feet long, and its crest is 16.25 feet above Chicago Datum. No water flows over this dam until the volume passing the water gauge above it exceeds 300,000 cubic feet per minute. The benefit, to Chicago, of this defense against Desplaines floods is incalculable. The entire cost of the River Diversion Improvement will closely approximate \$1,000,000.

The bridging on this work presents no serious problems on the rock sections. On these we shall use the ordinary draw bridge with unequal arms, the shorter one counter-weighted; the pivot-pier to be on one side of the channel, which will thus be left free and unobstructed. On the earth sections the pivot piers must be placed in mid-channel, and, inasmuch as the clear water-way on each side will probably be 110 feet, it will be seen that where the angle of crossing is necessarily acute, as in the case of one or two of the railroads, a very long bridge will be involved. One such bridge, which we have under advisement, will be 480 feet over all. A six-track bridge will be required where we cross the tracks of the Panhandle, Stock Yards, and Northern Pacific Railroads. For this situation I am hopeful that a leaf or folding bridge can be successfully designed and used. We are now wrestling with several railroad problems of great importance to us and to the other parties in interest, but the discussion of these at this time would be premature.

The tabulated statements accompanying the report of the Superintendent of Construction, Mr. U. W. Weston, for the month of June, are both interesting and instructive, as showing the progress made throughout the work.

Progress is rated upon a money basis. The estimated cost of each section is divided by the number of months allotted for its performance. Rating by yardage, that is, dividing the total yardage by months allotted for doing the work, would be giving equal periods for moving equal volumes of the cheap tractable and the costly intractable materials, whereas the money rating makes the more rapid movement of the tractable materials imperative.

A condensed statement, showing the magnitude of the work, will not be out of place here.

MAIN CHANNEL.

Glacial Drift	26,421,186 cubic yards.
Solid Rock	11,775,404 " "
Retaining Walls	304,734 " "

RIVER DIVERSION.

Glacial Drift	1,658,384 cubic yards.
Solid Rock	260,561 " "

MAIN CHANNEL AND RIVER DIVERSION COMBINED.

Glacial Drift	28,079,570 cubic yards.
Solid Rock	12,035,965 " "

Total Excavation	40,115,535 " "
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TOTAL COST, AS PER REVISED ESTIMATES.

Construction Account	\$20,377,048 40
Right of Way	2,603,227 92
	<hr/>
	\$22,980,276 32

This estimate is entirely exclusive of engineering and other administrative expenses.

With this introduction I will leave the field clear to my co-workers who will from time to time present this Society with papers relating to the work under their control, giving descriptions in detail of the several mechanical devices used, with statements showing their efficiency, as proven by the work accomplished. We may also expect contributions to the stock of knowledge relating to the flow of water in open channels over dams, etc., deduced from observations and flood measurements extending over long periods and made under varying conditions by our hydraulic engineers.

My prologue ends here. Should it be my privilege to carry this great work to completion, I shall feel a pardonable pride then in asking you to listen to the epilogue.

THE USE OF STEEL IN LARGE BUILDINGS.

BY CORYDON T. PURDY, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS
AND OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

[Read before the Boston Society of Civil Engineers, January 23, 1895.*]

THE use of steel in the construction of large buildings has opened a new and extensive field for the work of engineers, but its value to the profession is only gradually being realized.

Such buildings, as a whole, have attracted attention more than has the use of the steel in their construction. The one can be criticised more easily than the other. When a building is finished it stands exposed to public view, with all its advantages and its faults, while the steel used in its construction is covered up quickly and is as quickly forgotten by the majority of men. It may be good or bad, no one knows the difference; and so, some of the most wonderful things about great buildings, their frames, the great power plants that throb day and

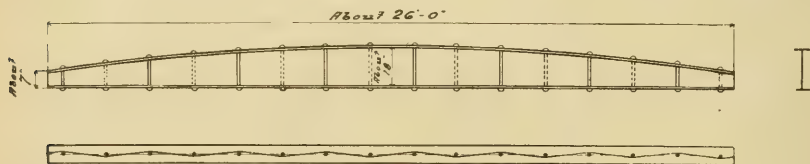


FIG. 1.

night somewhere beneath them, and much of their hidden mechanism, is comparatively unknown.

It would be very difficult to determine exactly when and how iron was first used in the construction of buildings. Cast-iron columns and lintels have been in use, of course, for many years, but the substitution of wrought iron and steel and the introduction of the present methods of their use are comparatively recent. Indeed, there are few things even in this progressive age of ours, which have developed and improved as rapidly as the use of structural metals. This is true in its application to bridges and buildings, and to all other forms of construction. Some of the most common adaptations and combinations of rolled iron were not thought of forty or fifty years ago, as can be clearly shown by the comparison of present types with almost any old ones that can be found. There is an excellent illustration of this in some iron girders (Fig. 1) which were removed from Sedgwick Hall at Lenox, Mass., a

* Manuscript received February 22, 1895.—*Secretary, Ass'n. Eng. Socs.*

few years ago. They were each made of three plates, a top and a bottom one, both horizontal, with a vertical corrugated web plate between, the corrugations running up and down. The three pieces were fastened together with vertical bolts extending through the top and bottom plates, about 20 inches apart, and alternating, one on this side and the next on the other side of the vertical plate, the transmission of strains from the web to the flange depending entirely upon friction. These beams were probably placed in position about 1840, and some of them still remain in the building. The designer evidently understood that more metal was required at the top and bottom of the beam than in the center, but did not understand the relation of shear and bending stresses and the necessity of a proper connection between the web and the flanges.

The first iron beams made in this country were rolled at Trenton, N. J., in 1853, and the first steel beams produced in this country were manufactured by Carnegie, as late as 1885.

The modern building constructed with a steel skeleton frame is quite a different thing from the building of twenty or even ten years ago. In the old buildings, beams and columns were an adjunct to the masonry work; in the new ones the relation is reversed. The masonry walls are not needed for their strength. In the very modern buildings they are cut into small parts and carried on the steel frame. Their exterior appearance is, therefore, entirely deceptive. In the old buildings, iron, when used at all, was used in disjointed and disconnected pieces, the various parts having little relation to, or dependence on, each other; while in the new buildings, the steel frame is a unit—a complete whole—the members of which are closely related to each other and dependent on each other. In the old buildings the structural metal was comparatively an unimportant item, while now it is the most important one. The words “old” and “new” are used here as referring to the two types of construction—the one dependent entirely upon its masonry for support, and the other dependent entirely upon the iron for support—rather than to time; for it must be borne in mind that both types of construction, as well as every possible combination of the different features of the two types, are now being employed everywhere in this country. Indeed, now that the value of the steel frame is becoming established, it seems as if every possible eccentricity and absurdity is pushing itself forward for recognition.

The most important difference, however, between old and new buildings, is in the construction of exterior walls, which, in the typical building, are entirely supported from floor to floor on the steel frame. This, however, gives rise to two other marked differences. As the walls in the new buildings are supported at every floor, the window areas may

be made very much greater, and, as the walls carry no load, they may be made thinner—16 inches being ample in the West. This increased window area is very important in smoky cities, and the floor area gained by the thinness of the walls is important wherever great buildings are called for.

The complete support of floors upon columns makes it possible to omit heavy interior walls and to put partitions anywhere in the new buildings or to omit them entirely or to put them in and take them out at any time without really injuring the building. Still another difference relates to the foundations. As walls tend to diffuse loads and columns tend to concentrate them, the use of the latter in the new buildings renders the foundation problem more definite and thus, to some extent, more simple.

This reversal of building methods, this change about in the function and use of masonry walls, and the introduction of such new conditions in large buildings is a real revolution, the extent of which can hardly be realized.

It has gone on in the East and in the West simultaneously, but not in the same way. In both places it has been a process of evolution, but industrial interests, the building laws, and the greater conservatism of the East have tended to retard it here, while in the West industrial interests have stimulated it more than they have retarded it, and the remarkable enterprise of Chicago has made such great demands upon both architects and engineers that they have been forced to be progressive. The result is that the constructive side of the problem has reached its most perfect development in Chicago practice. This is generally true in spite of some most excellent work in the East and some very poor work in Chicago. The rapidity and history of its development can be very readily traced in that City. A new idea is tried to a limited extent in one building, a bolder application of it is attempted in the next; another idea, originating in another office, is worked out in the same way. Thus the evolution proceeds and honors are extremely hard to divide.

Mr. Jenney, Mr. Burnham and Messrs. Holabird & Roche, of Chicago, have taken the most important part in this movement. Chicago's pride is its Auditorium, designed by Messrs. Adler & Sullivan; and other notable work has been done there by other architects, but these have led the way in the use of steel. It is easy to use a method that some one else has demonstrated to be practicable—a good deal easier than to attempt an innovation, at another man's expense, amidst adverse criticism, and with one's own future in the balance, even if one feels very sure he is right. It is because these men have done so much without precedent, in just this way, that it seems as if their names ought to

be permanently linked with the introduction of the use of steel in buildings.

The differences between the eastern and western phases of this forward movement has not been due to a difference in men, however. It has been due rather to a difference in conditions, circumstances and opportunities, and, while the pioneer work has been done chiefly in the West, some of the heaviest work has been done in the East. Mr. Post, of New York City, whom Mr. Burnham called the father of big buildings, was educated as an engineer, and he is, in many ways, as closely identified with the introduction of steel as are these Western men. The East has also the greater wealth, and it is continually making greater demands on architects and engineers. Without question, the greatest engineering problems in the construction of buildings—possibly the greatest in the history of the world—will arise in these closing years of the nineteenth century, and in the eastern cities of these United States. Western architects are recognizing this fact, and they will invade the East with their work, even as Eastern men have continually found clients in the West.

The change to steel construction is forced. The classical student has no liking for it. Stone and heavy masonry have always been what they seemed to be, and honesty is one of the first principles of art. The use of steel, therefore, forces brick and stone to violate this fundamental ideal of architecture. One of our oldest New York architects recently said, "We don't like it; we don't like it, but we've got to use it." Commercial interests tend to overbalance all other considerations, East as well as West.

The need for an engineer comes in at this point. The demand for steel has grown out of its many advantages—the economy of floor area, the greater height to which buildings may be carried, the increased lighting capacity, the larger liberty in the arrangement of rooms and like considerations; but the ability to use it well depends upon other things,—upon its safety and its durability, upon a technical knowledge of strains and of the strength of materials—and these are engineering problems. The first question in the construction of a building is one of utility; then comes that of safety and economy; and with this beginning the building problem both divides and multiplies itself rapidly. Every architect who has designed a large building knows how true this is. Most of the questions do not affect the construction at all, and the architect can deal with them without the aid of an engineer. Others affect the work of construction, and yet must be finally decided by the architect. The questions, however, involving a technical knowledge of the strength of materials, shop practice and metallurgy, are purely of an engineering nature, and, so far as the architect concerns himself with

them, he is acting as an engineer. In older days, and in the design of smaller buildings, the questions concerning their strength were determined chiefly by experience and precedent and less by scientific considerations, and it is only with the advent of steel that the engineer has become a necessity. But, while these questions of strength and endurance are in general purely technical, and are entirely independent of all the other problems in the building, the final result is so closely identified with its architecture and its utility that the engineer cannot possibly succeed in producing a satisfactory design unless every feature of his work is made acceptable to all these other considerations. Indeed his success in this line of work, and his ability to lighten the labors of the architect, depend quite as largely upon his ability to appreciate what is required in the building in every way, and to anticipate the wants of the architect with whom he works, as upon his technical knowledge as an engineer. He must really be both an architect and an engineer; an architect at least so far as construction and commercial considerations are concerned.

The purely technical questions involved are practically the same in all buildings, and first among them is the question of strength, the strength of beams, the strength of columns, and the lateral strength of the building.

The strength of beams is well understood, and the formulæ which apply are mostly simple and easily handled; though many of the calculations are rendered tedious by a complicated distribution and arrangement of loads. Error is most likely to occur in the fixing of the point of maximum moment and in the application of principles or formulæ, especially in beams where the points of reaction are not well determined or where the length of the beams is to be so fixed to obtain given reactions or certain moments of resistance, as very often occurs in foundation work. It often happens that the points of maximum moment must be calculated, and it is quite possible that the maximum moment, or one almost equal to the maximum, may occur at two or more sections of a given beam. The loads which beams must carry are fixed by law in most cities, but the architect and the engineer cannot depend upon legal requirements. Beams should, of course, first of all, carry the dead load, that is, their own weight and the weight of other material actually resting upon them. Then, if the beam is in the floor, or is in any wise subject to the effect of a movable load, an appropriate allowance should be made for that. The floors of a warehouse recently designed in Chicago were made strong enough to carry 640 pounds per square foot of the tributary floor, and this was not too great. In this respect, however, building laws are sometimes needlessly burdensome. Both New York and Boston require 100 pounds on office floors, whereas

60 or 70 is quite sufficient, provided there are proper restriction in regard to safes. The use of 16,000 pounds per square inch as the working stress of the outermost fibre is almost universal, but this must occasionally be reduced to prevent too great deflection.

The column question presents an entirely different problem. Here there is no uniformity of practice and no uniformity in legal requirements; indeed, the laws relating to the subject are more antiquated, than the practice. Column formulæ are not simple, and their real values are in question. They are all founded on an exact condition of concentric loading, whereas that condition rarely exists in building work and the departure from it is often so great that a blind use of any formula would be dangerous. The results obtained under these circumstances are always unsatisfactory. The formulæ are also cumbersome, involving much tedious labor, and, in these days when work must oftentimes be done rapidly and at small cost, the loss of time and extra expense involved on this account is considerable. If a man has a hundred columns to dimension, ten minutes on each would aggregate two good days of labor, and many buildings contain five hundred or a thousand. We must provide for eccentricity of loading, and the formulæ in use are not readily adjusted to any such complication of the problem.

Prof. Johnson, of Washington University, in a recent number of *Engineering News*, deplors the many attempts made during the last few years to disprove the ordinarily accepted principles of mechanics, as applied to the strength of beams and columns. In his exact statement he is certainly right, but, so far as the formulæ in use for the calculations of columns fail to express such accepted and well proved principles of mechanics, or so far as such formulæ represent conditions which we do not deal with in practice, we certainly have a right to question their real usefulness.

We want a simple column formula which will apply under all conditions of loading, which can be used rapidly, and which will give satisfactory results. When the moment of resistance of a beam under a definite condition of loading indicates that the outermost fibre is not strained more than 16,000 pounds per square inch of section, we know definitely and exactly what factor of safety exists in the beam. We want just such definite knowledge as this about columns. Prof. Mansfield Merriman's recent paper on the "Rational Design of Columns" points directly toward this end. He states: "When the true theoretical column formula is established, it will be unnecessary to state it in a specification, but, as is now done for beams, a simple requirement like the following will be alone needed: 'The maximum unit-stress on the columns shall not exceed, for wrought iron, 8,000 pounds per square

inch, under the action of live loads, and 16,000 pounds per square inch under dead loads.'” This is a perfectly rational statement. What we want always to be sure of is, that our columns have a given factor of safety; or, in other words, that the maximum fibre strain is not greater than one-third or one-half, as the case may be, of the elastic limit of the material. But this column formula will not be valuable, even if it gives us this maximum fibre stress, unless it is so comprehensive that it will cover all conditions of loading, and all conditions and sections of columns, and unless it is so certain in its results that we can place our entire dependence upon it. Prof. Merriman has taken a long step in this direction, and his paper is well worth careful study.

Three factors enter, or should enter, into a perfect column formula, viz: the direct concentric load, the influence of flexure and the effect of eccentricity of loading or of horizontal loads. Prof. Johnson brings out these three factors in the discussion of columns in Chapter IX of his new book entitled “Modern Framed Structures,” though the third element is omitted in the formula which he finally derives. The second element, that is the influence of flexure, is not nearly so important in its requirements, as the effect of eccentricity of loading, and might, possibly, be omitted from this formula, which we want for practical use in designing columns for buildings. Certainly the error would be slight within proper limitations. Prof. Merriman covers the same ground in the paper referred to. He states that “when a rational formula is established, for a long column it will reduce to Euler’s expression and for a short prism it will reduce to the simple expression for pure compression.” Later he shows in his table that the maximum fibre-stress under concentric loading, in columns of the dimensions in ordinary use in building work, does not exceed by more than 2 to 5 per cent. the total load divided by the section of the column in square inches. If this result be true, and it has not been questioned, we shall be safe, until we can do better, in treating ordinary columns in building work as being in direct compression, only adding always sufficient metal to provide for the eccentricity of the load.

This method is given in detail in the Chap. XXVIII. of Prof. Johnson’s work, and is, in effect, as follows:

First: Find the section required for the total load, both eccentric and concentric, when treated as a concentric load.

Second: Find half the width of the column, and the radius of gyration of the section in the plane of the eccentric loading.

Third: From the equation

$$\text{Area} = \frac{\text{the bending moment} \times \text{half the width of the column}}{\text{the allowed unit-stress} \times \text{the radius of gyration squared}},$$

we find the area of section to resist the bending moment arising from whatever cause.

Fourth : If this second area can be added to the first assumed area of section, without materially changing the radius of gyration and half the width of column, it may be done, thus obtaining the total area of section without a new solution.

Fifth : If the radius of gyration and half the width of the column must be changed in order to provide sufficient area of section, or if it seems advisable to change them for economy, then a new assumed section is taken and the radius of gyration and half the width of the column found for it, and the solution proceeds as before.

The formula that we want, must be something better than this, however, for this involves the use of the radius of gyration of the column and cannot be used rapidly without a very complete table of sections with their moments of inertia and radii of gyration. Even then, its operations require too much time.

But the strength of columns does not depend entirely upon what might be called the formula considerations. The shape of the section, the number of pieces which must be riveted together to form it if made of rolled material, the amount of riveting required and its position, and especially the manner in which the different pieces are connected when they are not riveted directly to each other, are all very important elements bearing upon the strength of columns. Suppose, for example, that we have several columns of the same length, of the same sectional area, of the same material, and of the same radius of gyration, but differing in design. Thus, one might be a Gray column, another a Phoenix column, a third might be made of plates and angles. It is possible that all of these conditions might practically be fulfilled. According to all standard column formulæ they would be equally strong under a concentric load ; whereas, in fact, even this is questionable while their resistances to an eccentric load are certain to be very unequal. Under direct bending, one half of the Gray column is practically neutral, and the two parts of the other half are not directly connected, while the column made of plates and angles is as well designed to resist bending as a box girder. This illustration shows two extremes. If these columns are not equal in strength under concentric loading, the inequality must be due to these considerations of form and assembling, which are therefore only second in importance to those of the theoretical formula.

The character of the material, the workmanship in the shop, and the detailing of the connections of column to column and of beams to columns are still a third class of considerations, altogether too important to be neglected.

The relative value of cast-iron and steel columns ought to have a place in this consideration, though other things beside the question of strength bear quite as pertinently on their relative value. The days in which cast-iron columns will be used in the construction of high build-

ings are fast being numbered. It would hardly seem necessary to compare them with steel columns before an audience of New England men, if we will but recall the Pemberton mill disaster, with its frightful loss of life. If cast iron is used at all, it should be in buildings of moderate size, with a very large factor of safety, with very careful designing and with the closest inspection. It is true that we have some very large buildings, both in the East and in the West, constructed with cast-iron columns; but that is no proof of their value or advantage.

Until within the last three years or so, the use of such columns had no more able supporter than Mr. Jenney of Chicago. At the last annual meeting of the American Institute of Architects he referred to the finding of an imperfection in a cast-iron column which illustrates their unreliability so well that it is worth recording in detail. It is shown in Fig. 2. He says:

"The pig iron used was excellent and satisfied all tests, and the exterior workmanship was all that could be desired. There was not a flaw or a blemish anywhere visible until the inspector applied the sound test, tapping gently over the surface with a light hammer and listening

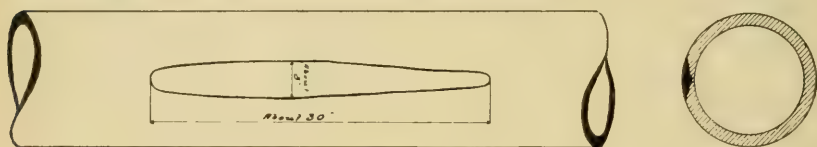


FIG. 2.

attentively for any variation in sound. At one place on the column he thought he noticed a change, extending along the column some considerable distance. Outside of this limited area the ring was clear, within it the sound was less so. He went over this repeatedly, looking for some external indication. All that he could find was a little scratch which seemed to have been made by the thumb nail in the sand of the mould, and did not in any way suggest a defect. He, however, called for a cold chisel and hammer and drove it in where this scratch appeared. Instantly there jumped out a cold shut about 30 inches long and varying from 2 to 4 inches in width. The thickness along the outer edge was scarcely more than a sixteenth of an inch, and at places even less so, while in the center it was fully $\frac{3}{4}$ inch. Both the surfaces of this cold shut, that is the under side of the piece that came out and the surface of the hollow remaining, were bright plumbago. It afterwards appeared that the plumbago, which had been used as a wash on the mould, had floated off in the iron, and, by introducing this thin film of plumbago on the interior of the melted iron, prevented a junction and formed this cold shut. Had this been on the interior of the column, which was quite as

likely to have occurred as on the outside, it would never have been detected. As it was, it would have escaped any ordinary inspection."

In this case the thickness of the metal was the same entirely around the column, but the cores in the mould are liable to be pushed out of place when the casting is made, making the metal thick on one side and thin on the other. Improper detailing may easily result in initial stresses. Flaws are as liable to occur on the inside as on the outside, where they cannot be detected, and when the column gives way, if it gives way at all, it does so without any warning.

The building laws in most large cities state the loads which columns must be made to carry. In all cases the column must carry the dead load which is tributary to it regardless of the requirements of the law. In New York City it specifies that the columns must carry all the live load from each and every floor which the floor beams are required to carry. This is excessive. It is quite possible that any given beam may be fully loaded, but it is so improbable that any column would be fully loaded that a considerable reduction might safely and wisely be made. The factor of safety for columns depends much on the use of the building. In most buildings where a proper allowance has been made for eccentricity of loads and for all other unusual conditions, a factor of two under the elastic limit of the material ought to be ample. Building laws attempt to regulate this also, but their provisions in regard to the matter differ radically in different cities and are incomplete.

Next to beams and columns the most important problem relating to the strength of a building concerns its resistance to lateral movements of any kind, whether they tend to induce a permanent deformation or are only oscillations and vibrations. It is possible that a building may sustain more or less of the latter without suffering permanent injury, but they make it unpleasant for those who occupy the building. It is especially important to guard against them in buildings the height of which is very great in proportion to the ground covered.

In any consideration of this problem we must first remember that many elements enter into it. The beam strength of a building depends entirely upon the strength of the beams, and, where there are no supporting walls, the columns are also entirely unaided in their function of carrying the weight of the building; whereas, steel bracing of any kind is assisted in its work, to some extent at least, by the weight and the condition, one or both, of all the material actually entering into the construction of the building. This makes any exact or scientific solution of the question exceedingly difficult, not particularly because of the stresses involved in the steel work, but because it is so difficult to determine the exact values of all these other factors which act in resistance to lateral deformation.

When a floor is well constructed, with floor beams and girders well connected to each other and to the columns, and with the arches, the concrete filling, and the finished floor all well made, it should act as a rigid horizontal plane, so rigid that a force applied at any point on its perimeter will be felt over its entire area, and will move it without deformation, if it moves at all. This is an important consideration. If floors are cut up by openings for stairs or elevators so that they are materially weakened, they should be strengthened with lateral rods over the tops or through the webs of the beams, to insure this rigid construction. In all high buildings this end should certainly be attained. When attained, there are two general conditions of deformation and two general ways in which lateral forces are resisted. A building may topple over as though it were a solid block, or these rigid floors may be moved over each other horizontally. Resistance to overturning depends upon the weight of the structure as a whole, and upon the area of ground covered, but the building cannot possibly overturn as a whole until the floors are so well connected and braced against horizontal lateral movement over each other, that the bracing is capable of lifting the weight of the building.

This condition can be attained in a tall, narrow steel building, but is never attained in an ordinary building. When we read of a building blown down, we read of a building that tumbles in and crushes down, but does not go over bodily.

The problem, therefore, resolves itself practically into that of so connecting and bracing the floors that they shall be able to resist this horizontal movement. The two general means for resisting lateral movements are, first, the gravity of the material and, second, lateral bracing. A wall standing alone will resist considerable wind pressure, not because of the tensile qualities of the masonry and the fact that it is braced at the ground, but because of its weight, the static condition of which must be disturbed before the wall will topple over. A large building may be built on columns—cast-iron columns, if you please—having little or no connection to each other, and the building may be completed from the second floor to its roof with the first story entirely open, with nothing except the naked columns connecting the part above with the ground below, and it will nevertheless stand a very great lateral pressure. Such a case actually occurred in Chicago, a building standing in this condition for months. This is possible, because there is a moment of resistance against toppling over, even when the base of the support is as small as the section of a cast-iron column.

This resisting moment becomes great if the weight is great. All the material in the building acts, to some extent, in this way, either directly or indirectly. The exact resisting value of a wall or a column

in this connection is a considerable problem of itself. Mr. Waite, of New York City, in a recent paper before the American Society of Civil Engineers, discussed this, giving some definite values, and his paper is well worth reading.

The other general means by which a lateral movement may be resisted, that is, by vertical bracing, concerns the strength of walls lengthwise instead of crosswise, the stiffness gained in the same way from partitions and the strength of the steel construction. In typical steel buildings, where walls are thin, light areas are large, and supports are at every floor, the lateral strength of the exterior walls, taken in this way, is not as great as that of the interior partitions, but the exact values of either are perhaps even more difficult to determine than their static resistance. The treatment of these very indefinite problems has heretofore received no rational or satisfactory solution. Even their approximate values are not to any extent agreed upon, and until they are agreed upon, we cannot know absolutely just what is required in the way of steel bracing of great buildings. Under these conditions the engineer should run no risk. If a building is without partitions, if exterior walls are thin and badly cut up, and especially if the proportions of the building are unfavorable, its lateral strength should be made secure in its steel frame.

There are three general methods of steel bracing; first, in the treatment of two adjacent columns and connecting web members of some sort, as a vertical cantilever truss fixed at the foundations; second, in the lateral stiffness of columns extending through two or more stories well spliced together at their joints, and alternating in the floors at which those joints occur; and, third, in same system of knee braces depending also upon the stiffness and strength of the connecting columns and beams and upon the manner in which they are connected. This last system is very often resorted to of necessity, where only a small bracing is desired, because it can be most easily employed without injury to the architecture or use of the building, and in spite of the fact that it is the most costly method and the most difficult to calculate properly. It is not suitable for heavy bracing,—that is for the resistance of a *considerable* lateral force, because it lacks in determinate efficiency as compared with the trussing arrangement first mentioned.

The continued columns cutting off at alternate floors have a still greater indeterminate efficiency. If they are employed throughout the building they certainly add very greatly to the stiffness of the structure, but it is very difficult to determine their value with exactness.

A fourth element of stiffness in all steel frames is the lateral strength gained in the connection of beams to beams, and more especially in that of beams to columns. The relative values of the different

methods employed in making such connections are shown to some extent in Figs. 3, 4, and 5. Fig. 3 shows the ordinary connection of beams to cast-iron columns. Fig. 4 shows one method of connecting beams to Phoenix columns. It is copied from the illustrated catalogue of Phoenix columns, published by Milliken Bros. Fig. 5 shows the connection of the beams to the Phoenix columns as designed for the Old Colony Building in Chicago. Where dependence is placed upon

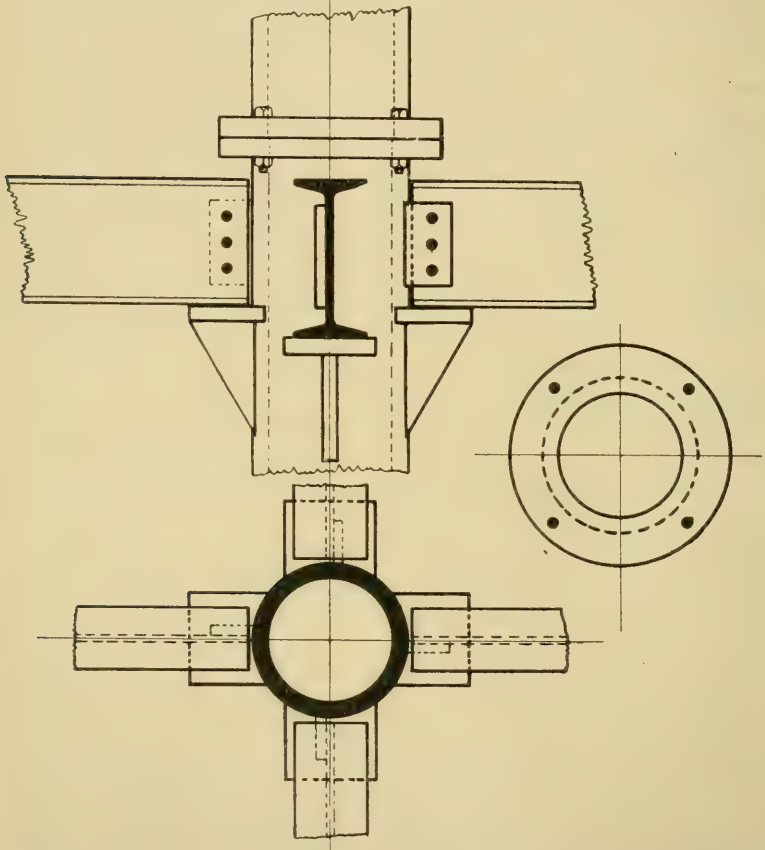


FIG. 3.—CONNECTION BETWEEN ROLLED BEAMS AND CAST-IRON COLUMNS.

continuous columns for stiffness, the character of these latter connections has much to do with the strength of this system. Whether the columns are continuous or not, the lateral strength gained by the connection of the beams to the columns, is, of course, in proportion to the number of rivets placed in such connections, and is greatly increased by making the connection through the flange instead of through the web.

The trussing system is by all odds the most efficient, and is the one which should be resorted to in all cases where great strength is required and definiteness is desired. The position, in a building, of a vertical truss or of a system of such trusses must depend very largely upon the architecture of the building and upon its intended use. In most buildings it is difficult to find room for such trussing, and all sorts of devices have occasionally to be resorted to in order to accomplish this important

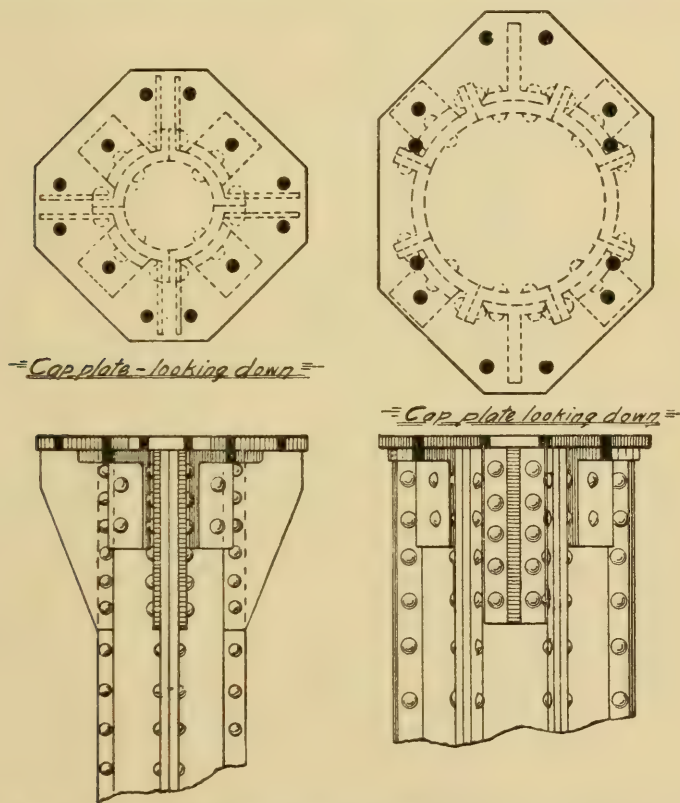


FIG. 4.—CONNECTION BETWEEN ROLLED BEAMS AND PHOENIX COLUMNS.

end. The bracing ought to be located symmetrically with reference to exposed areas, and it ought to be so arranged that it will surely receive all lateral strains to which the rigid floors are subjected. In any truss of this kind, if we may call it by that name, the columns become the chords, one being in compression and the other in tension. The total efficiency of such a truss is measured by the dead load in the tension column, that is, the total load of all the actual material which it carries. When the tension induced by the lateral resistance of the truss is greater

than this dead load, the column joints must be connected to resist the excess and the whole must be anchored to the foundations, or the columns will be lifted and the building injured. Such connections, however, are not practicable, and the conditions requiring them should therefore not be allowed to obtain. If the lateral resistance of a truss is not sufficient for the work required without putting the column in tension, an additional line of bracing should be provided.

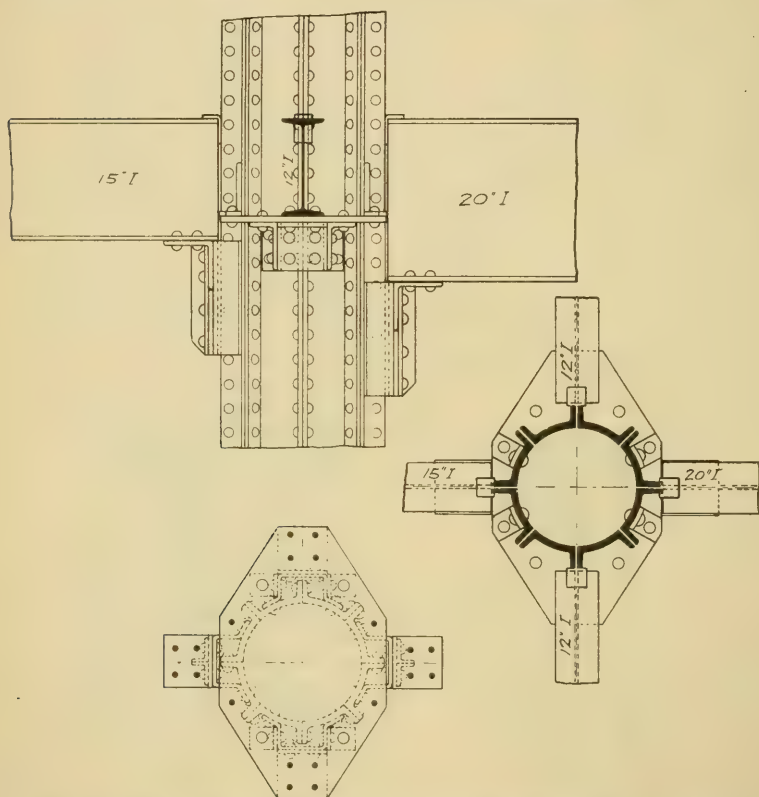


FIG. 5.—CONNECTION BETWEEN ROLLED BEAMS AND PHOENIX COLUMNS, AS DESIGNED FOR THE OLD COLONY BUILDING, CHICAGO.

The web members of such a truss can be made in a great variety of ways, and at this particular point the engineer has a good chance to use his genius in accomplishing his purpose without really injuring the building in its architecture or in its usefulness. An intelligent architect will appreciate the need, but he is not to be blamed for insisting very tenaciously that ways and means shall be found for doing the work without interfering with the best interest of the building in other ways.

If the space between the columns chosen can be converted into a solid wall, diagonal bars, pin-connected, with horizontal compression struts, can be used. These have an advantage in taking the strains directly, and are generally easy of erection. When the space cannot be converted into a solid wall, but can be utilized, with the exception of passage ways, the diagonals may often be made to pass through two or more stories, or parts of stories, and accomplish the same result without destroying such passage ways. Steel arches, however, can be made to perform the function of a web member, and still leave a space open to connect rooms on each side, sufficient for the ordinary purposes of one room. The transmission of strains is, of course, indirect, but the arches can be designed so that all the metal will be in service, in whichever way it is strained, whereas, in any scheme of diagonal rods, a double set must be provided for the same total work, and only one of these can be in service at a time.

In a large measure this compensates for the indirectness of the strains. The arch is a riveted member throughout, and has all its connections riveted. It is therefore subject to less minor vibrations than pin-connected bracing, just as a riveted viaduct or plate girder bridge is stiffer than a pin-connected structure. In some cases where buildings are on a yielding foundation, this is a point of considerable advantage.

The difference in cost is partially made up in another way. Pin-connected members of almost any form induce a bending moment in the columns to which they attach, or require an equal weight of additional metal in their connections, while the steel arches for portal bracing can be so designed that neither of these conditions shall exist. Any design for a system of bracing of this kind should be detailed in such a way that there will be no loose joints or chances for the various members to work themselves loose in the process of time. Yielding foundations are very apt to induce initial strains in vertical bracing of any sort, and especially in truss bracing, and any liability of this sort should not be overlooked.

This entire subject of steel wind bracing is illustrated by Figs. 6 to 12 inclusive. Fig. 6 shows a system of knee braces used in the Lees Building, Chicago. This arrangement of braces extends entirely across the building, just back of the elevators and near the middle of the building. Fig. 7 shows another system of knee braces employed in the exterior walls of the Music Temple, Chicago. Fig. 8 shows bracing in the shape of lattice girders in the court walls of the Tract Society Building, New York City. Fig. 9 shows an outline elevation of the portal bracing in the Old Colony Building of Chicago. It shows two lines of portals extending from the foundations to the roof. There are two other and similar lines, the four being symmetrically arranged in the

plan of the building. Fig. 10 shows one of these portals with its connections. Fig. 11 is a photographic view of a similar portal in the D. S. Morgan Building in Buffalo. Fig. 12 shows steel bracing with diagonal bars, also in the Morgan Building.

Very much has been written about the wind forces which buildings should be made to resist, and in some respects there is considerable diversity of opinion on the subject. It is pretty definitely determined,

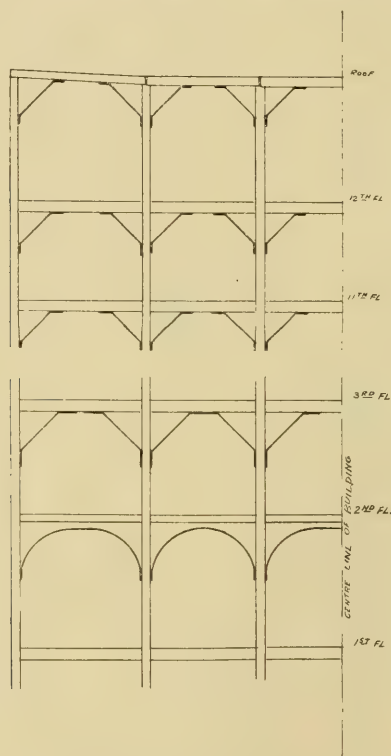


FIG. 6.—KNEE BRACING, LEES BUILDING, CHICAGO.

however, that the force of wind is usually greater at considerable heights than near the ground, though to even this there are exceptions. It is only a few years since heavy plate glass windows were blown into the bank on the second floor of the Home Insurance Building in Chicago, when lighter glass in the upper part of the building was entirely uninjured. It is also pretty well determined that a wind force of 30 pounds to the square foot is liable to occur, at not very rare intervals, in any part of the country. It seems as if we ought to be assured of resistance to 30 pounds of normal wind force per square foot over the entire side of a

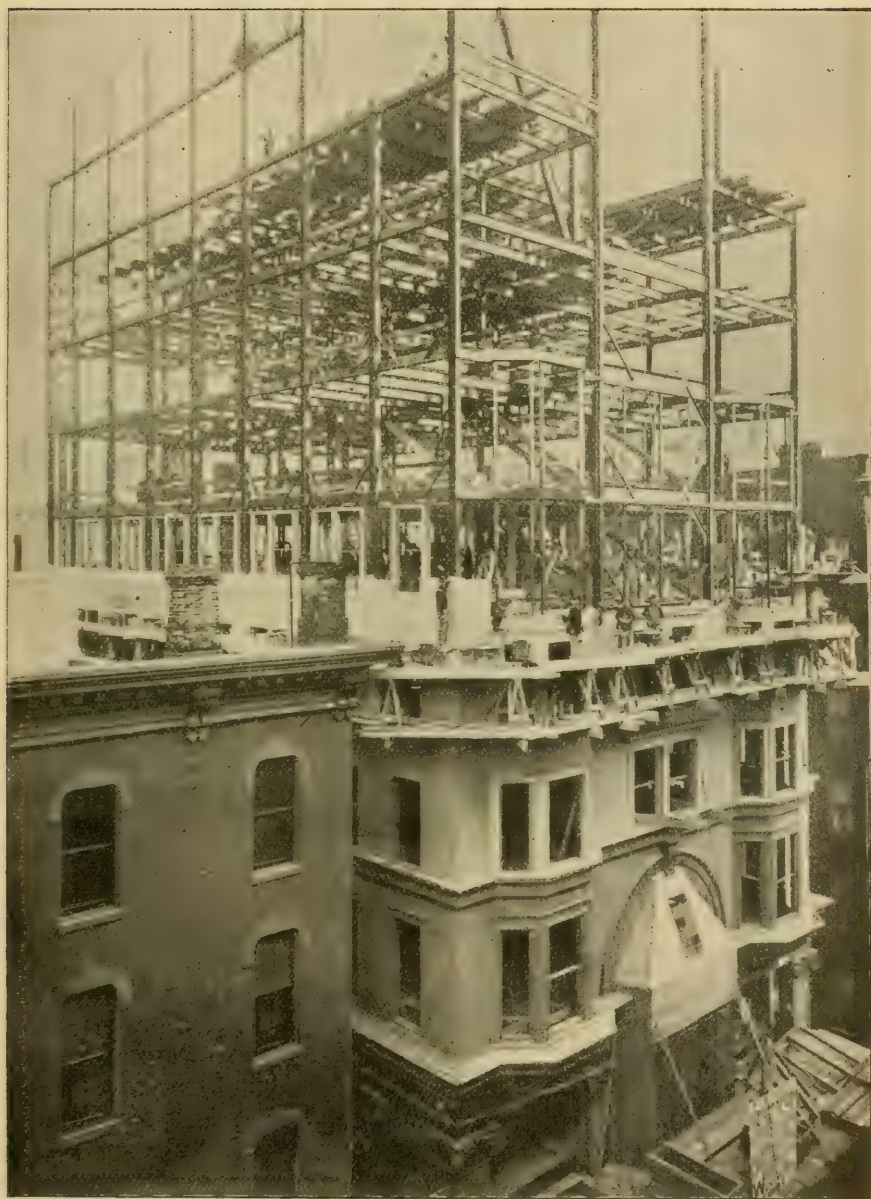


FIG. 7.—KNEE BRACING IN MUSIC TEMPLE, CHICAGO.

building, with a considerable factor of safety to cover any very unusual excess over this figure, or any defect in the material and workmanship used in the construction; and for unusual heights that this basis should not be less than 40 pounds. This requirement seems not excessive even when we consider that under ordinary circumstances such a force is exerted during only very short intervals and over small areas.

The building laws in some cities have nothing to say on this subject, and in all cities they are lacking in proper requirements. The extent to which steel should be strained in bracing depends somewhat upon the units of wind pressure used. If only the quality of the metal and the workmanship are to be considered, there seems to be no reason why 20,000 pounds per square inch in tension should not be used. No uniform

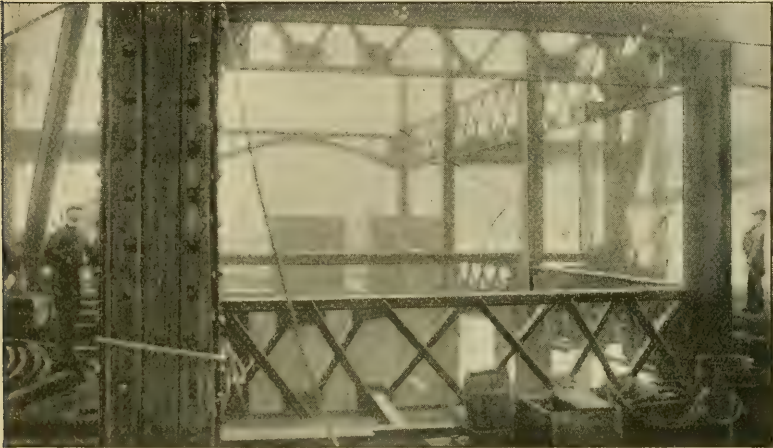


FIG. 8.—LATTICE-GIRDER BRACING, TRACT SOCIETY BUILDING, NEW YORK.

treatment of this subject is possible, for each building presents a separate problem. One of the greatest objections to the use of cast iron for columns in high buildings is its relation to this problem of lateral bracing. It is next to impossible to connect any efficient system of web members to such columns satisfactorily. The very fact that rivets cannot be used in cast iron is a sufficient objection to that material.

The efficiency of any bracing depends largely upon its absolute rigidity, and that rigidity cannot be obtained with loose bolts. The ordinary stiffness obtained in the splicing of steel columns, and in the riveted connections of beams to steel columns, is lacking when cast-iron columns are used, not only because the bolts are not as tight as the rivets; but because there are not so many of them, and because in the connection of the beams to the columns, the connection is near the

neutral axis of the beam instead of through its flanges. This is the greatest of all the objections to cast iron.

If engineers could agree upon the general principles governing the consideration of the subject, and especially if they could agree upon some way in which the resistance of other building materials to lateral strains could be determined, it would be a long step in advance of the present condition of affairs.

The protection of structural iron in buildings from corrosion is another great problem, and it ought to receive more attention than has hitherto been accorded to it. Fortunately, the conditions are not so

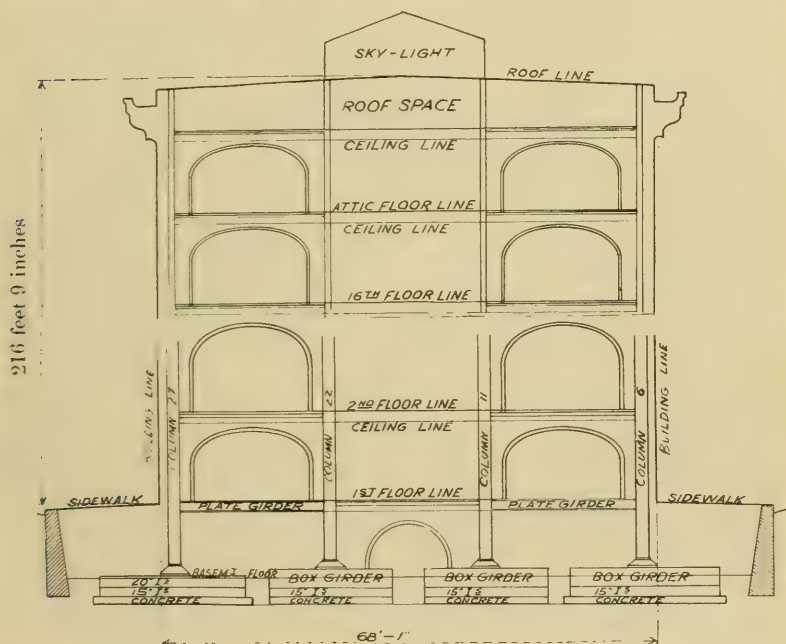


FIG. 9.—PORTAL BRACING, OLD COLONY BUILDING, CHICAGO.

difficult to overcome as those encountered in the effort to preserve iron ships, and structural iron in tunnels, in sea water, or even in ordinary bridges. Salt water is peculiarly destructive to iron in any form, causing corrosion in two ways, in the ordinary way where the material is exposed to both air and water and by galvanic action which it promotes wherever mill scale remains on the surface of the iron, or where different metals are used contiguously. Probably the most difficult problem of all pertaining to the preservation of iron and steel is the protection of the iron vessels used in salt water. The salt air along the coast is also very much worse in its corroding effects than the drier fresh air of the interior.

must understand and keep in mind the exact conditions of the phenomenon of rusting, if we are to clearly appreciate the character of this problem. Mr. M. P. Wood, an engineer in New York, in a recent paper on this subject, before the American Society of Mechanical Engineers, quotes from an article in the London *Engineer*:

"When rusting takes place under ordinary circumstances, the first stage appears to be the formation of ferrous carbonate. The carbonate is then dissolved in carbonic acid water to form ferrous bicarbonate, which latter is then decomposed in the presence of air and moisture, to



FIG. 11.—PORTAL BRACING, D. S. MORGAN BUILDING, BUFFALO, N. Y.

form hydrated ferric oxide, magnetic oxide being found as an intermediate product."

The paper states further "that neither bright iron nor steel will rust in pure water or in pure air. The presence of carbonic acid or some similar agent seems necessary, although the final product may be destitute of carbon. Even when oxygen, moisture and carbonic acid are all present, rusting will not take place unless the moisture condenses on the surface of the metal."

The force of this fact has a most practical illustration in the Baker Car Heater. This is a hot-water system, consisting of a heater, four to

five hundred feet of wrought-iron pipe and an air-chamber and drum usually fastened to the roof of the car. The water used for the circulation is saturated with salt, as much salt being used as the water will carry in solution. Some of these heaters were recently taken apart after

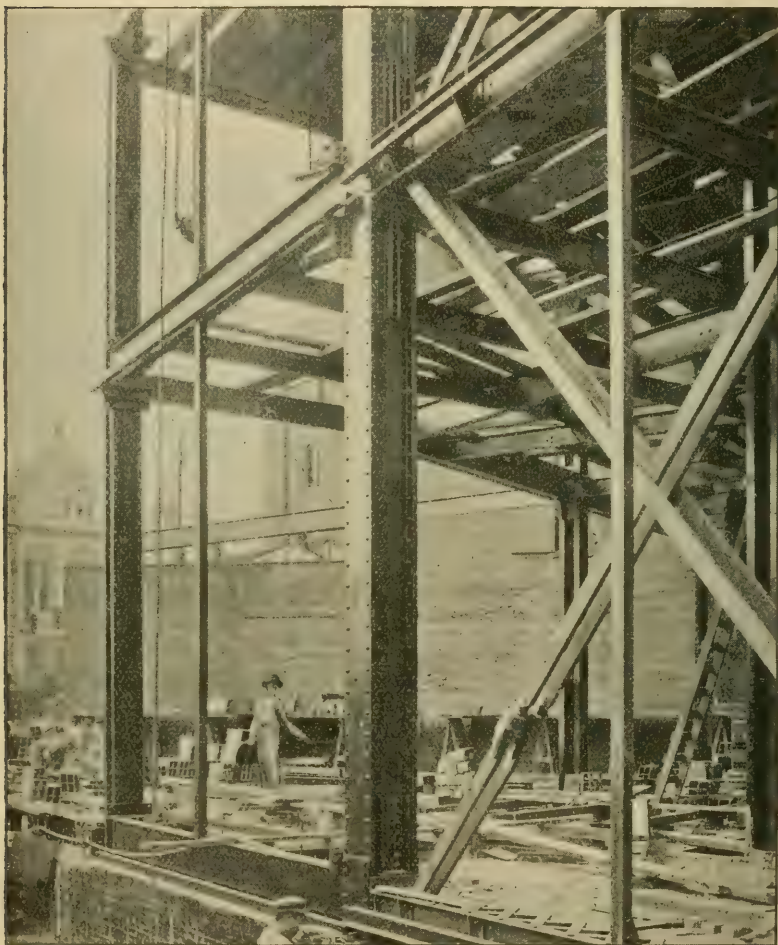


FIG. 12.—STEEL BRACING WITH DIAGONAL BARS, D. S. MORGAN BUILDING, BUFFALO, N. Y.

a service of nearly thirty years, and found to be entirely free from corrosion. The secret of this is in the complete exclusion of the air. If an iron column could be enclosed in a dry shell of fireproof material where the shell itself could not gather dampness, the column would last for-

ever, even if it were not painted; and, just to the extent that these conditions are realized, the fireproofing of the iron work in our large buildings is its best possible protection.

Danger of deterioration comes from the following sources:

- Exposure,
- Initial corrosion,
- Initial dampness,
- Permeability of fireproofing,
- Imperfect fireproofing,
- Leakage from pipes,
- Noxious gases, and
- Electrolysis.

In some buildings, structural metal is unnecessarily exposed, and exposure means corrosion unless the conditions are such that dampness can be excluded. The best interests of a building call for a complete and perfect covering of all the structural metal. This is done in a great variety of ways: Beams in floors are completely covered by the ordinary tile arches, using the word "tile" with its Western and better meaning. Interior columns are also covered with the hollow tile, while exterior columns are ordinarily covered with masonry. Several kinds of tile are used, both in floors and in partitions, and an indefinite variety of other materials and combinations of other materials, used and proposed for use in their stead. In the selection of these materials, their influence and effect upon the life of the steel work should not be overlooked.

Initial corrosion is another point very greatly neglected. Buildings are erected in both fair weather and foul, and care is rarely exercised to prevent any rusting before the iron work is enclosed. Yet who has not occasionally seen iron work in process of erection, which was completely encrusted with a layer of rust? A piece of clean iron or steel will, oftentimes, resist corrosion under very adverse circumstances, but when the rusting has once commenced, it is almost impossible to stop it. The ferric oxide is a great absorbent of both air and moisture. A spot of rust acts mechanically in bringing together the elements which are necessary to the chemical action. If the masonry covering absorbs moisture, the danger to the iron must be greatly increased by the presence, on its surface, of a body of rust. Even an initial condition of dampness ought to be avoided, because the iron might rust after it was covered, and then it would be as bad as if there had been initial corrosion. We occasionally see columns being covered in the wettest kind of weather, and it seems as if no one could afford the time to wait for the sunshine. There is a certain amount of initial dampness that cannot be avoided with our ordinary methods. So long as the coverings must

be constructed with wet mortar, we cannot have them perfectly dry at the start. But the danger from a damp wall often not touching the metal, as in the case of the fireproofing of columns, it is not near so great as that due to the actual presence of a considerable body of water clinging directly to the metal.

The first duty certainly is to take these simple precautions, concerning which there can be no question: cover all the metal, prevent corrosion before covering, and know that the metal is dry when it is covered. More than half the men who build great buildings do so with a view to large and immediate gains, and not to a conservative perpetual investment. The possibility of having a structural wreck in the next generation is not of so much importance as the saving of a very small margin of first cost, which these precautions would involve.

The permeability of different kinds of masonry, and of other walls used for enclosing structural iron, is very closely allied, in its relation to the durability of the metal, to the initial dampness due to wet mortar; and whatever destructive effects can grow out of the latter, can also grow out of the former when the permeability is great enough to permit a complete saturation.

The permeability of materials must not be confounded with their porosity. M. Paul Alexandre, a Frenchman, and Chief Engineer of Ponts et Chaussées, in discussing this subject at length, states that mortars mixed with fine sand are more porous than those mixed with coarse sand; but that mortars mixed with coarse sand are more permeable than those mixed with fine. Lime mortars are generally more porous than cement mortars. The permeability of lime mortars is not mentioned, but anyone who has lived under a leaky roof can testify to that. An increase in the proportion of cement in cement mortar decreases the permeability; age also decreases it; and all good Portland cement mortars become practically impermeable at the end of a few months.

Recently the fire insurance underwriters have outlined a scheme for a uniform and scientific rating of buildings, with reference to their fire risks. In a schedule which has been prepared for the purpose and which is largely used in Boston, New York and other cities, with a probability of a still more extended use, a premium is put upon what they consider safeguards against corrosion, consisting chiefly in the use of cast iron, instead of rolled material, and the use of lime mortar in contact instead of cement, while no penalty is provided for the omission of fireproof coverings around columns under certain conditions in certain buildings designated "fireproof." This fact is referred to in this connection, because it is very noteworthy that they should make this discrimination, and because the wisdom of the safeguards by which they

propose to preserve the iron work against corrosion, is questionable. If M. Alexandre's experiments and conclusions are correct, this schedule must be wrong in the statement that "cement must never be used in contact with iron or wood." Fr. Von Emperger, who has observed widely the practical working of Portland cement concrete and iron in combination, in the so-called "Monier system" for bridge and viaduct construction, and who is in this country now as a representative of the Austrian railways, states recently in a paper before the American Society of Civil Engineers that "concrete is the best conservator of iron," and more, that "it is a better protection than paint;" and supports his opinion by important illustrations in actual practice. If he is not right in his conclusion, pray tell us what will become of our far-famed Chicago foundations? Brick is, undoubtedly, a greater absorbent than mortars. The permeability of hollow tiles varies, but the possibility of passing moisture through them must be lessened by their hollow form.

The use of hollow tile around exterior columns between the masonry and the metal, as is done in the best western practice, is of unquestionable advantage in prolonging the life of the columns.

By imperfect fireproofing is meant partial, and badly arranged or badly constructed, fireproofing. Brick arches cover the webs of beams, but do not cover their lower flanges; holes through the fireproofing for the passage of pipes or for any cause whatsoever, make the work imperfect; and the omission of fireproofing in places to fix wooden grounds, or to otherwise connect interior finish, is exceedingly bad. The practice of placing centers of exterior columns so close to the building line that only a few inches of masonry, either brick or stone, can be put outside of them, is also very unwise. In some respects imperfect fireproofing is worse than no fireproofing. If the imperfection admits moisture and atmosphere where their work can go on unseen, a member may be ruined before anyone realizes that the process of destruction is going on.

Though the history of steel construction of buildings is limited, there are already some good illustrations of the quick and complete ruin that is certain to result wherever air and dampness can get into these hidden places. Recently, at the annual meeting of the American Institute of Architects, and later at a regular meeting of the American Society of Civil Engineers, Mr. Post, of New York, referred to the condition of some of the beams taken out of the old Times Building in New York City, after a service of about a quarter of a century. These beams carried brick arches on the lower flanges, the bottoms of the beams being uncovered. The corrosion evidently began at the bottom, but it crept upward between the iron and the masonry until the whole body of the beam was involved. The webs were entirely destroyed and

the flanges nearly so. The products of the oxidation looked more like hematite than iron. The room under these beams was used as a kitchen, and they were exposed to the steam and gases from a cooking-range. One of the peculiar girders shown in Fig. 1, which was taken from Sedgwick's Hall at Lenox, Mass., had been exposed near a door in the basement where the rain and snow could occasionally blow in and lodge upon it. When it was removed, not long ago, these exposed parts were found in this same complete state of oxidation; what was originally strong iron could be broken away easily with the hand. Some very interesting pieces of both of these badly oxidized beams have been preserved by Mr. Robert Maynicke, of New York City.

Engineers cannot control all these conditions. The responsibility rests with equal, if not with greater, weight upon the architects. Their specifications for fireproofing should be very stringent on every point where practical precautions can be readily taken, as in this particular of complete and perfect fireproofing on every part. They should also secure the isolation of all pipes, keeping them outside of the fireproofing of the columns. Even if there is no leakage of steam or water, or of gases that are worse than either, from vent pipes, the fireproofing must be broken wherever connections are made, and that alone is sufficient reason for keeping them removed.

All noxious gases arising from the sanitation of the building or from any other source, should by no possibility be allowed to come in contact with the iron.

The effect of electrolysis on iron has come to public notice so recently that the exact conditions under which it can occur are but partially understood. We do know definitely, however, that magnetic currents promote oxidation. We also know that such currents are due to induction as well as to primary circuit. The insulation of electric wires in conduits is certainly a wise precaution even from this point of view.

The relative resistance of cast iron, wrought iron and steel to corrosion has been given an undue prominence in many discussions of this subject, for the other problems and conditions relating to their use, in a large measure control their selection. Steel is corroded more rapidly than wrought iron, and both steel and wrought iron are corroded more rapidly than cast iron. The use of steel and wrought iron in many pieces, with the strength of the whole dependent upon the rivets which hold them together, is, in this connection, another disadvantage, for the moisture that collects in the edges and the corners is held to do its mischievous work, while that upon the more exposed and continuous surfaces disappears. Avoiding the greater danger by the use of the least tractable metal, cast iron, is only begging the problem and half meeting the issue. Cast iron has its proper place and its proper use, but in very

high buildings we *must* have the lateral strength that comes from the use of hot rivets, and the stiffness and assurance of strength that come from the use of rolled material. Wrought iron, also, is out of the race, for it is practically out of the market, and its lack of strength, as compared with steel, is more than enough to make up the difference in their resistances to corrosion. And that difference is less than it is sometimes supposed to be. Cast iron is by no means everlasting. Mr. Wood, in his last paper on this subject, states that the greater resistance of cast iron to corrosion when exposed to sea water or to air charged with sea vapors "is probably due to the surface of the cast iron being covered with a skin of silicate of protoxide of iron produced by the molten metal fusing the sand in the mould, as well as to the film of magnetic oxide of iron formed at the same time by oxidation of the hot metal." If this is true, and it would seem to be a very rational conclusion, it would be especially true of heavy cast-iron columns. The collation of authentic testimony bearing on this question would be interesting, but ever so much of it will not solve the main problem, that is, the complete protection and preservation of all the structural metal. The underwriters are already discriminating against the general neglect to satisfactorily meet the whole problem; and they propose to discriminate more closely as the condition of the iron buildings already erected shows increased deterioration. Yet their interest in it is a bagatelle, as compared with that of the investor in such buildings, or with the responsibility of the architects and engineers. The deterioration of the metal can increase the fire risk in only two ways: a collapse of some part of the building might cause a fire, or it might increase the loss in a fire started in some other way. Some of our large buildings have a day population of several thousands; if there is any danger of a collapse involving a fire hazard, there is an equal danger of imperiling the lives of many a people.

Again, even the possibility of a collapse on account of corrosion is extremely questionable; it is not probable, it is hardly possible; but the loss of the entire building is absolutely certain if the steel frame is not made good against corrosion. It will finally show its own rottenness, and will have to be taken down. The insurance man charges for the little risk he carries and seeks to define it as best he can; while the investor stakes his all, and gambles against a dead certain loss. It is hard to tell which is most to be criticised, the man who does the gambling, or the architects and engineers who help him to do it. It seems as if engineers and investors in all departments of construction were blind to the future. Mr. Wood, whom we have already quoted, says also,— "that corrosion will be so strongly developed in the Frith of Forth Bridge before fifty years have passed, that a drastic plan will have to be

adopted to prevent its destruction, and that because of the mistakes and neglect to properly care for it at the beginning, its life through the centuries will only be had through tribulation and sorrow." The miles of elevated railroad in New York are getting to be long streets of rust. We need somebody to blow a bugle blast so loud and so strong that legislators will hear, and that professional opinion will call with unanimity for special measures.

Without question, all iron work should have some preservative treatment in the shop, if not in the rolling mill. The mill scale is a dangerous element and ought to be removed from all iron work which it is seriously proposed to make everlasting. Rust should never be allowed to gather on such work. The best paint is a good preventive, but the ordinary painting of iron work in this day is wretched beyond all comparison. The paints themselves are bad, the oils are fishy, the paint is put on over scale and dirt and grease, in the rain as well as in the sunlight, over rust quite as willingly as on a bright surface, and without any particular care as to its completeness. A recent examination of two columns standing side by side in a New York building and painted by one of our leading manufacturers, is a good illustration of the general result. The paint on one had, as it were, dried up, and to a large extent disappeared, as if it had been a coat of powder. The paint on the other was sticky and blistered, and could be pulled off in long patches like pieces of thin leather, and possibly the two columns were painted at the same time and out of the same pot.

The ideal paint must have no ingredients that can deteriorate iron or steel, or in any way promote their corrosion. Such a paint must cling tightly to the metal; it must dry quickly; it must set with a surface hard and smooth, but tough enough to resist injury in handling or otherwise; and it must be unaffected by atmosphere, water, or gas, or by heat or cold. The ordinary paints in the markets, with their multifarious adulterations, are of little value to meet these specifications. Pure red oxide of lead, mixed with pure linseed oil and applied immediately, has, up to date, given the best results, with the possible exception of the graphite paint manufactured in Detroit, the true value of which is not yet determined. The red-lead, however, must be applied immediately after mixing, or it will not cling to the metal. Iron oxide paint promotes rather than prevents oxidation, and should not be used on structural iron. Zinc-white blisters; lamp-black is not hard. Mr. Wood's treatment of the subject of paints in his recent article is quite complete, and his references to other literature on the subject are exceedingly valuable. The graphite paint referred to is a comparatively new product, manufactured from native ore obtained in the Lake Superior region. It becomes hard very quickly after being applied; a

characteristic which, the makers claim, is due to the proportions of alumina and silica contained in the ore. It clings tightly to the metal, does not blister, sets hard, and seems to be exceedingly tough. The manufacturers have an ordinary grain bag saturated with this paint, which has hung, full of water, in their factory for three years. During this time the water has twice been frozen solid, and the bag itself is apparently as pliable to-day as before the paint was applied. Canvas saturated with the paint is also fireproof to ordinary exposure. Altogether, it is very worthy of the careful investigation of engineers and architects. All paints should be applied upon clean metal. Painters sometimes prefer to apply paint over rusted surfaces, because they say it sticks better. The chances are, however, that paint applied in that way will not be weatherproof, that the oxide already found will absorb both air and moisture, and that the corrosion will go on underneath the paint unobserved. It is claimed for the graphite paint that its chemical characteristics are so antagonistic to moisture in every form that the paint will counteract such injurious tendencies; yet the fact remains that all paints should be applied to clean surfaces, which should also be dry, and, if possible, warm. Wet surfaces prevent the paint from clinging to the metal and cause blistering. Where iron work is exposed to underground dampness, as it always is in foundation work, waterproofing courses of asphalt are of unquestionable advantage; and hot asphalt applied to iron work so exposed can be used instead of paint, but the value of such applications will depend largely upon the quality of the material and the thoroughness with which it is applied.

Much has already been said about fireproofing as a protection against corrosion, but our treatment of the general subject would hardly be complete without some reference to fireproofing as a fire protection. It is very necessary that the large buildings, which the use of steel has made possible, should be absolutely fireproof. This is true, not only because the number of people who occupy them and the value of the property in them are very great, but because their greater height increases the difficulty of exit and makes it extremely difficult for firemen to operate. Such buildings ought to be made absolutely and completely fireproof against any fire within or without. A great many criticisms have been written about fireproof buildings that burn, so much so that there is a popular notion that no really fireproof buildings can be built. Such statements were common after both the great fires in Boston, but the president of one of the leading insurance companies states that not a single building destroyed by these fires was rated as fireproof; and it is quite notable that the only building left standing in the business center of Chicago after its great fire, survived because it was indeed fireproof.

Our opportunities to judge accurately by observation concerning

the values of the various methods which are used to make the fireproofing complete and perfect, are exceedingly limited. Generally, when fires occur in fireproof buildings, they are so insignificant that no record is made of them; and when fires occur in buildings that are not fireproof, the destruction is so complete that it is difficult to estimate the value of whatever good fireproofing may have been in the building. During the last few years, there have been several fires in the Rookery in Chicago, and one of them, at least, would have consumed the building, if it had not been a fireproof structure. In the interior of the building are a number of janitors' closets, one right over the other. As they could not be ventilated through windows, iron gratings were put in the floors, and the whole system was ventilated, every room through those above it. Every night the refuse of the building is gathered temporarily in these rooms. The fire started on one of the lower floors as soon as the material was gathered for the day. In a moment the entire stack of rooms was a blazing furnace, and the heat must have been intense. Everything in them that could burn was consumed. The work of the firemen had, probably, little to do with stopping the fire. The damage was very small. It showed a weak point in the construction of these rooms, but also proved that the building was well constructed to resist fire.

Probably the most remarkable illustration of the fact that buildings can really be built fireproof is afforded by the fire in the Chicago Athletic Building. This building, constructed by the Chicago Athletic Association, is about 84 feet wide, by 170 feet long, and eleven stories high. The fire occurred shortly after its completion, and the damage was confined to the portion above the third floor. The fifth floor is all one room, a great gymnasium, with a running track extending entirely around it about ten feet above the floor. Heavy steel box girders about 40 feet long, and a few zee bar columns, supported the high ceiling of this room and all the floors above. The upper floors are used for bedrooms, dining-rooms, and courts for indoor tennis and other games. The interior finish is solid oak, all the halls being wainscoted with it, and all the walls and the ceiling of the gymnasium being covered with it. Indeed, it even covered the columns. At the time the fire occurred, this finishing material was all in place, and the painters were just finishing the dark antique finish in the gymnasium. The false work, made of 2-inch plank, erected for the workmen engaged in the erection of the heavy paneled ceiling, extended, with its supports, over the entire area of the room. Carpenters' benches and chests occupied every vacant place; some thousands of feet of lumber were piled in the room, awaiting use in other parts of the building, and the heavy oak floor was covered with shavings, blocks and other refuse. The fire, which was undoubtedly of incendiary origin, consumed everything combustible

that was in this room, and so thoroughly that it was difficult to find even charred pieces. The intense heat can be better imagined than described, most of the wood-work in other rooms was consumed, even the floor being burned away in many places. The total loss was reported to be about \$60,000. The damaged steel work, however, was replaced for a very small amount, not more than a few hundred dollars. The only beams that were exposed were between the elevators, and the expansion of the iron guides buckled them all. The chief loss occurred in the destruction of the delicate stone tracery in the front of the building; and this was due more to the water thrown upon it, than to the fire. The strength of the building, both in its masonry and in its steel construction, was not in the least impaired; the tile arches in the floors were not injured to the extent of having to be renewed.

The most important lesson which the fire taught, pertains to the fireproofing of columns. In this case, the long columns in the gymnasium were not properly cared for. Before any fireproofing was put around them, they were encircled, at about every four feet in height, by wooden frames made of 2x4-inch scantlings spiked together. These were for grounds, and to provide a backing to which the oak wainscoting could be nailed. Betwixt these strips, the columns were enclosed in hollow tile blocks in the ordinary way. The fire burned these frames, and the covering of the columns dropped to the floor. The columns, fortunately, were not injured, but that fact is not to the credit of good fireproofing. If the columns had given way, the destruction of the building would have been complete, but the real fault would never have been known, and meritable measures would have been condemned.

The fireproofing around columns should be continuous from floor to floor; it should be well constructed, and the pieces should be anchored together entirely around each column, preferably with copper wire, every four or five feet in height. The space between the fireproofing and the iron should be left vacant. Columns in the exterior walls should be covered with the hollow tile just as thoroughly as those in the interior; and should have, at least, five inches of brick work or other masonry well laid in cement mortar between this and the outer air. The hollow spaces are just as important around the exterior as around the interior columns; and the five inches outside of the fireproofing will give space for the width of one brick and a well-laid coat of Portland cement between it and the fireproofing. Lime mortar should not be used for this work. If the character of the brick requires it, or if, for any other reason, lime mortar is necessary, a coating of some waterproof material should be used outside of the fireproofing.

Four inches of brick work alone, between the steel work and the outer air, is not good for protection against either fire or corrosion, while

four or five inches of limestone is almost no protection at all, and should never be permitted. Marble and limestone are not fireproofing materials. The New York Building Law provides for the use of bond stone in heavy brick masonry. The use of limestone in this way endangers the whole structure. Where limestone and marble are used to finish the front of a building, it should be done in such a way that the strength of the structure does not materially depend upon it, and so that the masonry can be replaced in case of injury. The risk that is run in using limestone for an exterior finish and in relying upon it for the strength of the building, was never better shown than in the Athletic Building. The loss of the stone work in this fire was very great, but the steel work, over the part of the wall which was destroyed, preserved the front in the upper stories, so that it was not materially injured.

The whole subject is too great for a proper consideration here, but it may be emphasized that buildings can be made completely fireproof, by covering all the iron work with the hollow material made for the purpose, and fastening it in position so that it cannot be readily tumbled down or stripped off. The air spaces will prevent the heating of the metal to a danger point, either by yielding or by expanding. Almost any material made in hollow block form will serve the purpose, if it can be protected; but if it is exposed, so that water can be thrown on it while heated, it should be of porous material, for the very hard clay tiles are apt to crack to pieces under such treatment.

Non-inflammable materials for interior finish are desirable. Stocks of goods that can readily burn, or quantities of inflammable materials, should not be allowed in buildings above the convenient reach of firemen, say seven or eight stories—but the steel can be protected so that the building will not burn even if they do. The use of metal in buildings is demanded, and this and all the other problems that belong to it can be, and must be, satisfactorily solved.

NOTES ON A BROKEN PINION SHAFT.

BY ONWARD BATES, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read October 3, 1894.*]

ON July 8, 1893, a breakage occurred to a pinion shaft operating the C. M. & St. P. Ry. drawbridge over the Menominee River at Milwaukee, showing so peculiar a fracture that photographs were taken of it, two of which are submitted for the inspection of members of the Society, with the following notes compiled from a report of the accident by Peter Sullivan, the Railway Company's Iron Bridge Inspector.

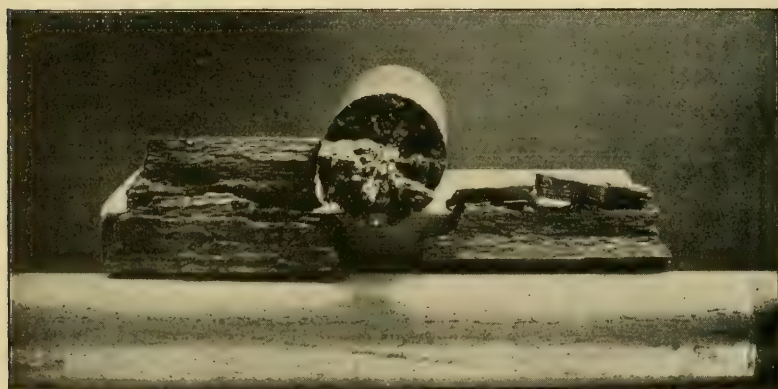
The bridge is a double-track iron structure, 203 feet long, built in 1886 and opened to traffic December 19th, of that year. The failure was the first of its kind, and did not cause any interruption to either railway or river traffic, as the bridge is provided with separate hand-turning gear. A new shaft was provided and put in service the day after the accident, and it was again operated by steam power. The bridge is easily turned by two men with the hand gear, and when steam power is applied, a boiler pressure of 30 pounds is usually carried. Complete reports of river traffic through the draw openings are not at hand, but there are records of the bridge being opened 10,417 times in 1893, and 11,997 times in 1892. It is estimated that it was opened 12,000 times per year previous to 1892.

The broken shaft is one of two pinion shafts, each $3\frac{7}{8}$ inches in diameter by 4 feet $3\frac{1}{2}$ inches long, working in sleeve brackets 3 feet, $1\frac{1}{2}$ inches long, with bearings $8\frac{1}{2}$ inches long at each end. The upper end of each shaft is fitted with a spur wheel 26 inches diameter and 5 inches face, driven by an intermediate shaft which, in turn, is driven by an equalizing shaft acting through bevel gearing. The intermediate shafts have their bevel wheels set in opposite ways, one with the bevel up and the other with the bevel down, in order that they shall turn in the same direction while being driven from the opposite ends of the equalizing shaft. To provide for disengaging the other gearing from the pinion shafts when the bridge is operated by hand, one of the bevel wheels is made to slide on a feather, and the other has a clutch coupling. After the accident, the feather was found to fit snugly in its seat in the hub of the bevel wheel, and the clutch coupling to have nearly an inch of play, or lost motion, where it engaged with its bevel wheel. The significance of these fits will appear hereafter in accounting for the

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broken shaft. The lower ends of the pinion shafts are fitted with spur pinions, $11\frac{1}{2}$ inches in diameter and 6 inches face, engaging with the rack circle on the pier. The pinion shafts are geared to the engine in the ratio of 1 to 25, and revolve about seven times in opening or closing the bridge, which ordinarily occupies about forty seconds.

When the shaft failed and was removed, it was found that the break had occurred inside of the sleeve bracket, about six inches from the lower end, with the fracture extending upwards nearly twelve inches. Between these points the shaft was completely broken in two places about five inches apart, with the short section split in four pieces. The photographs, which are a little over one-sixth size, show the broken shaft plainly. It is to be noticed that the appearance of the fracture is as if the shaft were a wooden one covered with black oil. Indeed, the small pieces of the shaft were taken to be of wood by some who saw them.



The shaft which was broken is the one operated by the loose-fitting clutch coupling. Mr. Sullivan's theory of the break, with which the writer agrees, is that it was due to the shocks caused by the one-inch lost motion in the coupling in starting and stopping the bridge. Counting four shocks (starting twice and stopping twice) to each time the bridge was opened, there were approximately 315,000 shocks applied to the shaft, and alternating in torsional direction. The shaft was of badly welded iron, and, in being twisted back and forth with jerks, the seams gradually opened and the oil used in lubricating the shaft penetrated between the parts, lessening the friction between them, and this process continued with the pieces held together in the sleeve until they were completely broken, as shown in the photographs.

This theory of the fracture is supported by the example of the other shaft, to which the power is applied by the bevel wheel sliding on a

feather without any lost motion, and which is in apparently good condition, although doing the same work as the broken one.

The clutch was evidently made with too much play at first and this perhaps was increased by wear. The mass of the moving structure was so great that with a force suddenly applied to the shaft, the resistance was similar to that of an immovable body and the shock was to be measured by the power of the engine. Such shafts under unfavorable conditions are subjected to heavy stresses, and for example it may be mentioned that on two different occasions steel shafts 5 inches in diameter were twisted in two in the Kinzie Street railroad bridge, in Chicago, before it was rebuilt.

The writer makes no apology for choosing as his subject a small detail when he might have presented a whole bridge to the Society, for he wishes to draw the moral that correct designing means attention to



details, and that we cannot know all about details until we have learned their wearing qualities.

MR. GOLDMARK.—Was the shaft made by rolling or by hammering?

MR. FINLEY.—By rolling.

MR. GOLDMARK.—This is a case where wrought iron failed because it was wrought iron, because it consisted of a number of layers the seams of which were not properly welded. The author speaks of this as a badly designed detail, but it is a question whether the design or the material is bad. In other words, would it not have opened just as much in a 5 inch shaft as in a $3\frac{1}{2}$ inch shaft? Those who have had something to do with rolled iron shafting have often come across this opening in

welds. Wrought iron, which by many is still considered far more reliable than steel, has, in this case, as in many others, shown unexpected weakness.

MR. ARTINGSTALL.—Why is it that we recite in our specifications that the size of ingot and the size of hammer shall be under the direction of the engineer, excepting that it is to see that the metal is properly worked? I judge that in this case the metal has not been properly worked.

A METHOD OF MAKING RIVER SURVEYS BY STADIA EXCLUSIVELY.

BY J. L. VAN ORNUM, ASSOC. M. AM. SOC. C. E.

[Read before the Engineers' Club of St. Louis, January 16, 1895.]

FOR a complete survey of a river, where latitudes and longitudes, as well as the most exact location of all the salient features of the river and its surrounding territory, are desired, no method can supplant a complete triangulation system. Also, in the case of a river of great size, whose territory is extensive and whose width is great, a system of triangles throughout its extent and the location of soundings by angular measurements are essential. Minor modifications are often made, and details changed to suit varying conditions under which the work is carried on; but whenever a river, from its size or importance, requires the most exact survey possible, recourse is necessarily had to the extensive, though expensive, system of triangulation, with the accompanying intersection system of locating soundings.

Mr. Walter G. Kirkpatrick (in a paper read before the Engineering Association of the South), has suggested a modification of the well-known triangulation methods, in which their exactitude is relaxed in the interest of economy and speed. This method involves triangulation also, but of a much more temporary and approximate character.

Its principles, as set forth, involve a network of triangles covering the river, the stations on one bank being opposite those on the other, and on the ground near the water's edge. Stations are spaced at a distance about equal to the width of the river. A base line, from one station to the next adjacent one, is measured every thirty or forty stations, in order to check the work. In measuring the angles, the transit occupies stations on only one side of the river, the supplementary angles on the opposite bank being computed. In this way the triangulation is effected, and from its data the computation of necessary distances is easily and quickly made and the plotting simplified by the use of the system of chords, the checks being numerous.

The author does not state his recommendation for completing the meandering more in detail, nor for the location of soundings. Presumably any of the usual methods might be used. This modified triangulation method would seem to be applicable where the usual littoral growth of standing and overhanging trees, brush and often cane, become so light as not to interfere seriously with the necessary lines of sight along the occupied bank.

For any ordinary river survey, the stadia method furnishes the best system, both because of its economy and on account of its efficiency. It is, of course, not so accurate as triangulation, yet its accuracy is amply sufficient for a survey for navigation or for improvements, or for any purpose up to the most rigorous if it is within the scope of the method. This scope limits it to rivers not much more than one-half mile in width, because the location of the soundings, as well as the meandering of the banks, is made by the stadia, and the sights must be kept within practicable limits of length. The following is the general plan of operations, in the light of which its efficiency and economy will be made more clear.

The purpose of a river survey is, in general, to determine its course throughout, its depths in detail, its slope, the position and character of its banks, the nature of its bed, its ruling velocities and its discharge at different stages. Should the purpose not require all these investigations in detail, the survey will be to that degree simplified.

In the stadia survey, five parties are required, viz., two transit parties, two level parties and one hydrographic party.

The two transit parties are similar in their work and in their personnel. The latter, in each party, consists of a transitman, two stadia-men and a boatman with a boat. All measurements are taken by stadia and directions by successive azimuths (or angular deviation from the meridian). Of the parties, one works, if possible, on each bank of the river, back from the usual littoral growth of trees, and so is generally unimpeded by them. Its duties are the accurate meandering of its own bank, the taking of the topography of the adjacent country back to the highest flood line where practicable, the noting of the character of the river banks, and the location of necessary points established by the hydrographic and level parties and described later. The meandering of the banks requires the surveyed line on each to follow the river's direction. It involves, besides the necessary located points, observations on polaris for azimuth at least every twenty miles of progress. Reciprocal sights for azimuth and distance should be exchanged between transitmen every two or three miles. Such sights furnish data from which the latitudes and departures of such circuits are computed, thus checking the work in the field. If an error of any magnitude, either in azimuth or in latitudes and departures, is discovered, the field work of the circuit is retraced, and the error found and corrected. The average error of closure should not exceed $7\frac{1}{10}$, and that of azimuth should not exceed $2'$ per mile; and the extreme limits allowed should not exceed double these amounts. The topographical points, and points located for the hydrographic and level parties, will be made by secondary (side) sights from the occupied stations of the closed lines.

A level party works on each bank, each carrying forward its level line. Each party contains a levelman, one rodman and one boatman with boat. Each party should, on its own bank, keep as nearly as possible abreast of the hydrographic party and take the elevation of water surfaces (located by the transit parties) at the time and place of sounding, as frequently as is necessary, *i. e.*, very frequently at bars or shoals and much less frequently at pools. Permanent bench-marks should be established at each shoal, and also between shoals, if the distance is greater than four or five miles. Reciprocal sights for elevation should be exchanged between the two levelmen every two or three miles, and, if a discrepancy of any size is discovered, the circuit should be re-leveled.

The hydrographic party is charged primarily with making the soundings, which are located by angle and stadia. It consists of a transitman (with his individual boatman and boat) and a large sounding-skiff containing a recorder, steersman, leadsman, stadia-man and two or three oarsmen.

The sounding boat will define lines from bank to bank, and also lines in the direction of the river's length, thus covering the river with a "gridiron" of sounding lines. These cross-lines and longitudinal lines will be at a distance apart depending on the purpose of the survey and upon the ascertained depth of water, the spacing being much closer in shoal water. Straight lines will be secured by the steersman, who will choose natural ranges on the bank ahead, or by other similar methods familiar to river men. The method of location herein recommended permits of constant oversight by the transitman, thus assuring at the time straight lines correctly spaced.

The general oversight of the party rests with the transitman, while the sounding boat is under the immediate charge of the recorder. The leadsman is in the bow of the boat and the stadia-man close to him, with his stadia-rod always vertical and facing the transitman. When working, the steersman keeps the boat on the desired line, and the leadsman takes the soundings (with lead-line or sounding-pole) as frequently as desired, calling to the recorder the depths and character of the river-bed. At the same time the transitman is taking his observations of stadia-reading and angle as frequently as possible, each location being timed to coincide with the vertical lead-line and the vertical hair being directed to the lead-line for the angular reading; the stadia-rod being so close to the leadsman makes it practicable to read the stadia interval, although it is not in the center of the field. The transitman records his observed stadia interval and then reads and records the corresponding angle, thus fixing the position of the sounding by polar co-ordinates.

The practicability of making accurate readings on a stadia-rod held in a boat depends mainly on care on the part of the transitman. In the boat, the stadia-rod should be well braced, at the bottom, in a temporary way, in each position, and the stadia-man should have a high and firm seat to enable him to hold his rod steadily in its vertical position. The transitman, having, for convenience, his transit generally near the water's edge, habitually keeps the lower hair at a reading about equal to his height of instrument above the water, thus requiring little movement of the gradienter to accurately place the lower hair for successive readings. When preparing for a sight, he turns the alidade with his left hand to bring the vertical cross-hair to coincide with the lead-line as it becomes vertical, while, at the same time, with his right hand he moves the gradienter whatever small amount is necessary to produce a coincidence. This preparation enables the transitman, when the vertical hair does coincide with the vertical lead-line, to note at the same instant the reading of the upper hair, and so read the interval. In this, as in other work, repeated observations soon lead to expertness. If the water is somewhat rough, the lower hair would usually stand at the mean height of the mark; then, at the critical instant, a quick movement of the gradienter will obtain a correct setting, which is read as before. The size and load of this boat also lessens the disturbing effect of the waves. Quite a sea is necessary to vitiate the readings, and when the water is rough enough to make them unreliable it is rough enough to vitiate the readings of the lead-line, and work should, of course, be stopped.

We must now consider the means of identifying corresponding observations in the books of the transitman and recorder,—that is, ascertaining which sounding recorded corresponds to each location. Time locations would furnish an accurate means, but, were this plan used, there would be lost one of the advantages of this method of location, viz., its elasticity, which allows the transitman to make as frequent locations as his manipulations will permit. To effect this object, the best plan is for the transitman to have his boatman or assistant wave a flag at the instant he makes a location; this is seen by the stadia-man in the boat and repeated to the recorder there, and both transitman and recorder make corresponding entries. To obviate error due to loss of a signal or to mistake, differently colored flags are irregularly used, and each field book shows a corresponding record of color opposite the proper entry. Thus both the transit book and the sounding book have a corresponding succession of color signals for each line, each location in the transit book applying to the sounding denoted by the correctly corresponding indicated color. Of course, the beginning and end of each line furnish distinctive points of identification and reference by

time observation, noted by both transitman and recorder, and, at the close of each day's work, the corresponding observations on each line, as identified by the color of flag, are numbered.

The particular advantages of the stadia method are economy, a greater frequency of location and a more thorough covering of the area, due to the fact that the position of the lines of soundings is instrumentally observed in such a way that they are subject to the perfect supervision and immediate correction of the transitman. This insures a complete covering of the area, without the necessity of an accompanying office force to plot the soundings in the field.

The positions of the transit are arbitrarily chosen to the best advantage as determined by the meanderings of the river, and are from one-fourth mile to one mile apart. Whenever the sounding lines have progressed a sufficient distance beyond the transit station, the latter is marked by a flag and abandoned by the transitman. He is then taken by his boatman to the next advantageous location for his station, while the sounding boat waits in position; then observations are continued from this place as before. Preparatory to measuring the location angles of soundings, the zero of the horizontal limb of the transit is always set either on one of the stations previously occupied by the transit, or on a station established for the purpose, and marked, as are the others, by a flag. The stations just mentioned are located from at least two stations occupied by one of the transit (bank) parties, thus connecting the meander and hydrographic surveys into one complete and connected whole. This fact makes it necessary for the hydrographic party to be always in advance, with the level parties as nearly abreast as possible and the transit parties closely following.

It will be found that the transit parties are often more than able to keep up with the hydrographic party. Their spare time can be advantageously employed in taking borings in the river bottom where necessary, and in velocity measurements and observations for cross-section and discharge, under the direction of the chief of party.

Gage readings to determine the stage of water at the time of survey, methods of reduction of soundings to equivalent depths at low-water stage, computation of low-water profile from that at the time of survey, discharge computations and other reductions and operations are made in the usual way, and do not properly come within the scope of this paper.

The system described is elastic, allowing modification to suit particular cases. Thus, if the stream should be a small one, permitting both banks to be within the reach of one transit and one level, a single transit party and a single level party would suffice where economy is necessary. In this case the level line would be checked approximately by transit

levels, and the transit distances by the hydrographic work. Or, if the greatest economy is desired, with a limit of accuracy such as is obtainable in compass work, a single instrument man with a transit will make the whole survey. In this extreme case, the meandering of the river would be by stadia sights and compass bearings, the stations being at the water's edge. Secondary sights would locate salient points of the banks, from all of which the bank line would be drawn. Level readings on the rods would give water surfaces for the profile and the reference plane of soundings, and, from the located points on the banks, the channel depths, as obtained, would be sketched in where of ample depth. Where the depth is questionable detailed surveys are made in the usual way, by polar co-ordinates, as is also the case where cross-sections for discharge are desired.

The rate of progress varies from six or seven miles per day, for the case last mentioned, to a mile or a mile and one-half per day for the most complete survey. The cost of field work would correspondingly vary from four or five to sixty or seventy dollars per mile.

The writer has used the system, as described in this paper, with its various modifications, on several river surveys aggregating over 400 miles. Hence the system has not only borne the test of experience, it is a growth developed by conditions and exigencies that have arisen in experience.

To restate the argument briefly, the particular advantages of this system of stadia hydrographic surveys are :

- (1) Economy.
- (2) Elasticity of adaptation to conditions.
- (3) More numerous locations of soundings.
- (4) A more accurate location of soundings than is often practicable by two transits on the bank taking simultaneous pointings, and a much more accurate location than is possible by the three-point problem, using a sextant in the boat.
- (5) Adequate and complete instrumental oversight of the work at the time.

ROAD IMPROVEMENTS IN KNOX COUNTY, TENNESSEE, AND FULTON COUNTY, GEORGIA.

BY J. E. M. HANCKEL, MEMBER OF THE ASSOCIATION OF ENGINEERS OF
VIRGINIA.

[Read January 26, 1895.]

I HAVE selected for discussion the road improvement system of Knox County, Tenn., and Fulton County, Ga., because they represent the same geological formations that confront us in our two sections of Virginia, known as Southwest Virginia, and Eastern or Piedmont Virginia.

Knox County, Tenn., abounds in limestone cliffs and ledges, that break out on the surface in all parts of the country. In building roads here, it is possible to open, at almost every mile, quarries which will furnish excellent macadam. On many miles of roads, the material from the cuts which are made in order to reduce the grades to the maximum (which is 5 per cent. except in emergency places), is a hard, blue limestone, and this is broken to proper sizes, put on the road-bed, and thoroughly rolled.

It is not necessary to present to you a description of the modes of construction used in this county. That they are good, is all that is necessary to say of them. The construction of new, and the improvement of old, roads is in charge of the Board of Pike Commissioners, the County Judge being Chairman of this Board. These Commissioners are permitted by law to employ, on their roads, all convicts committed by their County Courts; and the cost of supporting these convicts is met from the general funds of the county. With this force they build on an average eight miles of macadamized roads each year.

There is also levied a special road tax of 10 cents on \$100 worth of property in the county, including the taxable property in the incorporated cities. The funds derived from this tax also are placed in the hands of the Pike Commissioners; and with this they build about seven miles of macadamized road each year. This one county thus builds fifteen miles of macadamized road each year.

Leading out of Knoxville there are ten roads which are graded to a 4 per cent. grade, and so well macadamized that one can drive for ten or twelve miles in any direction on them in the worst winter weather at a brisk trot, and be able to plead not guilty to the charge of being a mud thrower. These roads have been made what they are, however under the most advantageous surroundings.

Turn now to the roads of Fulton County, Ga. The Commissioners who have shown themselves so efficient in Knox County, Tenn., would make many blunders here. The soil of this county is red clay, with quite a large percentage of mica. When this becomes wet under constant rains, the roads are almost impassable. Here there is some stone that can be quarried and crushed for macadamizing; but there is very little of it, and it grinds down rapidly under traffic and frost, and is then washed away by rains. These macadamized roads, therefore, soon become rough, and are very expensive to maintain in proper repair.

The roads are built and repaired under the direction of the County Commissioners, who appropriate each year a certain amount for roads. The general levy of the county is made on property in the city limits of Atlanta, as well as on all other property of the county. The Commissioners lease from the State about two hundred convicts, who are kept at work on the roads all the time.

These Commissioners have abandoned macadamizing altogether. They pave about fifteen feet of the roadway, altogether on one side, with cobble or common rubble, which they quarry and break into proper sizes instead of crushing to egg size. They pave from six to twelve miles of road per year with this force, and have already improved in this manner many miles of county roads.

I have shown that the two cities of Knoxville, Tenn., and Atlanta, Ga., besides maintaining their own highways, contribute (and, of course, by far the largest part) to the expense of building and maintaining the county roads. This is just, as all roads naturally lead to the important town or city of the county; and this town or city is better able to pay for such improvement, and will reap greater benefit from it, than any other part of the county.

I believe that we should have in Virginia such a road law as these counties have. We cannot expect the small values of county property to stand such taxation as would, of itself, provide sufficient funds for such road improvements as we must now inaugurate if we are to keep pace with our sister states. We have a State that is capable of just as much progress as these have made.

I trust that our Association will be the instrument of inaugurating in Virginia a good road system, the working of which will redeem our State from the disgrace now facing every county official.

COUNTRY ROAD BRIDGES.

BY C. C. WENTWORTH, MEMBER OF THE ASSOCIATION OF ENGINEERS OF VIRGINIA.

[Read October 17, 1894.*]

PART of the making of a good road lies in making the bridges good. A good bridge is one that at a reasonable first cost is strong and durable, accommodates the traffic, and requires the least yearly expenditure for its maintenance. The good appearance of the finished bridge is also to be considered; but for ordinary county road bridges that good effect in looks which always follows the execution of a well-planned engineering work may be relied on to fulfill this desideratum. A neatly designed portal is generally used to ornament the structure. It should be entirely devoid of the very slender open ironwork that is often found on portals and which is always disfiguring.

It may be stated that since iron structures can be built at almost as low a first cost as wooden ones, there should be as little wood used in the bridge as possible. Even the joists that carry the flooring should be of iron or steel; timber appears at present to be the material best adapted for the flooring itself. If metal joists are used, which are simply rolled beams, the cost of the bridge will probably not be increased beyond the amount expended in the first renewal of the timber joists. It is an easy matter to take up and renew a floor plank that shows signs of decay, but to renew or even examine the timber joists is a difficult undertaking.

The supports for the ends of the bridge should be of stone whenever stone can be procured. The plan of using iron cylinder piers is to be avoided if possible. Masonry ought to be made of reasonably well-shaped stone laid up in real cement mortar. The cement must set hard in a week or less. If the stones used are hard and durable, their shape is of little importance, provided they are all held together in a solid mass by good cement. In order to make good cement mortar it is absolutely necessary to have not only good cement, but also clean, sharp sand. By looking after these points, we can build at a low cost, a wall that will stand indefinitely, as far as the masonry is concerned. If no good stone can be procured, then iron cylinders of from $2\frac{1}{2}$ to 5 feet in diameter are used. These are made of iron plates not less than one-fourth of an inch in thickness, bent into a cylinder and riveted. Each pair is also braced together across the bridge. These cylinders are

* Copy received February 28, 1895.—*Secretary, Ass'n Eng. Socs.*

filled with concrete. A good plan is to bolt them to a platform of timber placed low enough to ensure its being always wet, so that they can not settle or be pushed over.

For short spans, up to say 30 feet, rolled beams can be used, with the floor plank laid directly on them. For longer spans there is no better form of bridge than that known as the Pratt truss. These are generally through bridges, or what are called half-through or pony trusses, the latter being used for spans up to about 80 feet. For very long spans, a modified form of Pratt truss is sometimes used, which has the ends of its top chord somewhat inclined, instead of being level. These are known as elliptic, or Baltimore trusses.

In pony-truss bridges the sides are from 6 to 10 feet in height, so that there is no room for overhead bracing to keep the top chords in position. This is the weak feature of a pony truss, and is to be guarded against by making the vertical posts with a rigid connection to every floor beam, so that by their stiffness they hold the top chord in place, the top of each post being connected to the top chord. There ought to be a post at each end of every cross floor beam, and the inclined end post should extend straight from the end of the span to the top of the first vertical post. There is used sometimes a kind of truss in which the end post meets the top chord at a point several feet from the top of the first vertical. This form should be entirely discarded, for the reason that every panel point of the top chord should have a vertical post to support it and keep it in line. It makes no difference how much the end post is inclined, provided the height of the side truss is kept one-sixth to one-tenth of the span. It is a good plan to make the vertical posts of a pony truss about 2 feet wide at their lower ends where they connect to the cross girder, and taper them up to the top, where they are made small enough to enter the top chord. The 2 feet of width of the base makes it convenient to connect them rigidly to the cross floor beam.

Through Pratt truss bridges are used for spans longer than 80 feet. These have inclined end posts, but, as the trusses are high enough to admit of cross bracing overhead, there is no need of the same dependence on the vertical posts to keep the top chords in place, so that the first vertical is made a tension member. The head room over the floor to the under side of the portal bracing should be not less than 14 feet.

The floor joists of all county road bridges ought to be proportioned to carry a live or rolling load of 100 pounds to the square foot of floor surface. This will provide for any heavy single load that may be met with on such roads, so that it can go anywhere on the bridge with safety. As it is not at all likely that a great number of such heavy loads will happen to be on the bridge at one time, so as to cover all the floor at once, the cross floor beams that come at every panel point may be pro-

portioned for a lighter load, 80 pounds per square foot of floor surface being sufficient for them. If the cross girders, or floor beams, are 15 feet apart and the roadway 12 feet wide, the capacity of each floor beam will be, by the above rule, 14,400 pounds, or say a wagon weighing 6 tons. If the bridge is packed full of cattle for a length of two panels, or say 30 feet, this is also provided for, and is the heaviest load that is likely to occur.

The trusses that carry the cross floor beams and joists of the roadway may be proportioned for a little less live load than the floor, for the reason, again, of the extreme unlikelihood of the whole bridge being fully loaded at one time. For bridges of 100-foot span, 80 pounds per square foot of floor is enough for the trusses. For 125-foot spans, 75 pounds is enough; for 150-foot spans, 70 pounds; for 175-foot spans, 65 pounds; and for 200-foot spans or over, 60 pounds is sufficient. In each case, the live load for the joists is 100 pounds per square foot, and the load for the cross floor beams is to be 80 pounds per square foot as before.

The length of the panels into which a truss is divided, depends on whether metal or timber joists are to be used. If these are of timber, the panels should not be more than 15 to 18 feet long, as long sticks are generally hard to get for renewals; and the longer the panels the more timber there is to renew per foot run of bridge. If metal joists are used there is no reason why panels of 20 to 23 feet long should not be used, and such panel length will be found to be economical; as then there are fewer panels, and fewer pieces for the bridge builders to make and erect. In this way the cost of a bridge with long panels and metal joists is rendered little if any greater than one with short panels and timber joists.

Timber joists should not be spaced more than 2 feet apart, and the floor plank should not be less than 2 inches in thickness. With joists 2 feet apart, the following sizes are proportioned to a live load of 100 pounds to the square foot of floor surface:

- 3 by 10 inch for 12-foot 3-inch span.
- 3 by 11 inch for 13-foot 6-inch span.
- 3 by 12 inch for 14-foot 9-inch span.
- 3 by 13 inch for 16-foot span.
- 3 by 14 inch for 17-foot 3-inch span.
- 3 by 15 inch for 18-foot 6-inch span.
- 3 by 16 inch for 19-foot 9-inch span.

These spans of from 12 feet 3 inches to 19 feet 9 inches, may of course be those of short span bridges of that length or the panel length of a truss bridge.

Steel joists, spaced 3 feet apart, may be used for the following spans or panel lengths, these being for the ordinary light sections rolled of the given depths.

Rolled beams 5 inches deep for 11-foot span.

Rolled beams 6 inches deep for 13-foot 6-inch span.

Rolled beams 7 inches deep for 16-foot span.

Rolled beams 8 inches deep for 18-foot 6-inch span.

Rolled beams 9 inches deep for 21-foot span.

Rolled beams 10 inches deep for 23-foot 6-inch span.

Rolled beams 12 inches deep for 28-foot 6-inch span.

Rolled beams 15 inches deep for 36-foot span.

With these spans the beams will deflect under the extreme load, but not enough to be objectionable for highway travel. These beams rest on the cross floor beams at the panel points, and these latter, for ordinary bridge spans, may be made of rolled beams also. For bridges with a 12-foot wide roadway, 12-inch beams will answer for panel lengths up to 17 feet; for a 14-foot roadway up to 13 feet; and for a 16-foot roadway up to 10-foot panel lengths. A 15-inch rolled beam will answer for panel length up to 27 feet for a 12-foot roadway, to 20 feet for a 14-foot roadway, and to 15 feet for a 16-foot roadway. These floor beams may be either suspended from the under side of the lower chords, or connected to the vertical posts above the lower chords. A good bridge can be built in either way, and one is no stronger for carrying travel than the other; for every point of a bridge is suspended in one way or another, and the point is to make the mode of suspension strong enough for its duty.

The floor plank should be laid squarely across the bridge, and never in more than one thickness, as the space between two thicknesses would hold water and dirt, which hasten the decay of the floor. To keep the hubs of the wheels from striking the trusses, there should be a line of guard timber bolted to the floor on each side of the roadway to hold the wheels at a safe distance. This, which it is well to have, renders unnecessary what is known as a hub plank, and a more unsightly object than a hub plank, warped out of shape and of no use, is hard to find. Also the abomination known as a lattice hub guard may well be discarded, as it is too low for a hand rail and too high from the floor to prevent a small animal from going under; and as a means of keeping hubs from the trusses, except by creating fear in the mind of the driver lest he should by chance hit it, it is not a success.

Just what to provide as a means of preventing a traveler from falling off the bridge is one of the unsettled points in the building of highway bridges. Five or six lines of iron rods from three-eighths to three-fourths inch in diameter strung through the center line of each truss are cheap, neat and effective. These can be joined together by threaded pipe couplings and tightened up against the end posts, through the center of which they pass. A wooden fence is as unsightly as the

hub plank, and is always out of repair. A gas pipe rail is better than the timber fence, but more expensive than either it or the iron rods mentioned above, while being no more effective than the latter.

The width of the roadway should not be less than 12 feet, and this only for bridges of less than 100 feet in total length. Where longer than this, two teams are apt to meet on the bridge, whereas on short spans one team can, if necessary, keep off while the other is crossing. For longer bridges, the width should be 14 feet in the clear, while a width of 16 feet in the clear is more desirable. A sidewalk is very seldom necessary on a highway bridge.

Now that we have determined the general dimensions of the bridge, and the load it is to carry, the next thing is to see that the structure will carry the loads for which it is designed. When iron first took the place of wood in bridge construction, the iron seemed to be a material so much stronger that too little iron was used, and for this reason many railroad and highway bridges had to be rebuilt. When steel took the place of iron, the same mistake was made, and engineers are now beginning to use steel more nearly as they would iron, and as they should in highway bridges. The steel used is not all like the steel in a razor or a handsaw, and the nearer it resembles iron in its properties the better. High-grade steel is too brittle to use in such structures, and if steel is subjected to high working stresses the bridge built of it is no stronger than one of iron, while the steel bridge is actually less rigid than the iron one under passing loads.

The working stress suitable for a tension member of a highway bridge is 12,500 pounds per square inch of the area of the cross section of the member, whether of iron or of steel. This is one-fourth of the ultimate capacity of iron, and one-fifth of the capacity of soft steel, in tension; so that, while the deflection under a load will be the same in either case, the steel structure will be the stronger as far as the tension members are concerned.

Compression members should be strained 10,000 pounds per square inch of their section. This is about one-fourth of the ultimate capacity of either iron or soft steel in compression for very short columns. For long columns this working stress has to be reduced by one of the usual formulas for the purpose—Gordon's, for instance. As an illustration of the working of the formula for reducing the allowable stress on long columns the following may serve, as the columns are generally made of two channels latticed, for the vertical posts, and with the addition of a cover-plate for the top chord and end posts.

If a post is 1 foot long the allowable stress is 10,000 pounds per square inch. If made of two 5-inch channels the allowable stress becomes only 5,000 pounds per square inch, if the column is 21 feet

long. In the same way two 6-inch channels become worth only 5,000 pounds per square inch at a length of 25 feet, 7-inch channels at 28 feet, 8-inch channels at 33 feet, 9-inch channels at 36 feet, 10-inch channels at 39 feet, and 12-inch channels at 46 feet.

As a general thing, the diameter of the pins that connect the members of a bridge will run from one-third to one-half the depth of the channels used in the chords.

It is manifestly impossible, in the limits of a paper like this, to go into such detail as will enable the services of an engineer to be dispensed with. As in medicine, the doctor must be relied on. The point is for business men to determine the doctor's ability and reliability.

WHAT OUR BAD ROADS COST US.

BY CLARENCE COLEMAN, MEMBER OF THE ASSOCIATION OF ENGINEERS OF VIRGINIA.

[Read October 17, 1894.*]

IN point of conception and invention, and in boldness of execution as a builder of the highest type of road known to science and art, the American of the nineteenth century stands pre-eminently in the front rank. Cities teeming with busy and thriving populations have sprung into existence, moved by the potent sign of the iron cross, made by these knights of the age of iron and steel. Fair fields are yielding rich harvests and paying their tribute to the commerce of the world in places that would have been inaccessible without the grand crusade of these modern knights, who have come, not like the knights of yore, leading their captives in their train and bearing their trophies on their shields, but, like the avatar of progress and science, leaving their indelible tracks in iron and steel emblazoned on the everlasting rocks.

The capitalist has been so lavish in creating and fostering these pathways of steel that to day 170,637 miles of railway in the United States represent in capital and funded debt the enormous and incomprehensible sum of \$10,268,169,042, while the total amount of money in the United States on the 1st of July, 1893, was only \$2,323,402,392. The general government has given 200,000,000 acres of the public domain and hypothecated its credit for \$100,000,000 in the interest of these vast schemes. Certainly the arteries of the country have been nourished to the neglect of the veins, and, as in the physical constitution of the animal organization, these systems of circulation are so correlated that the very existence of the body corporate depends upon their synchronous development and action; so in the body politic, one system of internal improvement, created and magnified to the utter exclusion of its correlated part, destroys the equilibrium of its own creation and saps the very foundation of commercial prosperity.

It is no marvel that the human mind has been actually entranced by the magnificent possibilities of the modern railroad. It is no wonder that the tiller of the soil has plodded over miles of highway of miry consistency and almost fathomless depth to offer his life earnings at the altar of this nineteenth century fetic. We would not deprecate the advance and progress of this great factor in human civilization, nor can we deprecate its transcendent results. It is in accordance with

* Copy received February 28, 1895.—*Secretary, Ass'n Eng. Soc.*

the natural order of things that capital should seek investment in the most skillfully managed concerns and that it should avoid such ignominious failure as the management of our common roads presents. Had the improvement of our highways kept pace with the development of our railroads, we would have advanced the hands on the clock of progress another hundred years.

There is an aphorism of political economists to the effect that "The civilization and prosperity of a State is measured by the condition of its highways." Then, if we are prepared to recognize the value of good roads, we must, by an inverse process of reasoning, admit the cost of bad roads. If we could follow the differentiations of value in the one case, and of cost in the other, it would not be difficult to determine the results; but the problem presents a moral as well as a mathematical condition, and, while it would be interesting to enter into the domain of speculative philosophy and to apply the axiom of cause and effect to each particular ramification of this comprehensive subject, it will perhaps be better suited to our purposes to deal with actual facts as they unfortunately exist with us in this State.

To arrive at any definite conclusions in regard to these facts, it is necessary to institute some basis of comparison, and for this purpose I have selected France as having the most complete and perfect system of highways in the world, and exhibiting a degree of domestic, commercial, and financial prosperity which is in a great measure due to the equipoise of her system of internal improvements.

The State of Virginia comprises an area of 40,125 square miles, and has a population of 1,655,989, or 41.27 inhabitants for each square mile of area. France, with an area of 204,000 square miles and a population of 38,125,395, has 186.88 inhabitants for each square mile of area. Virginia has a total railroad mileage of 3,426.43, or 11.71 square miles of territory for each mile of railroad. France has a total railroad mileage of 24,018, or 8.49 square miles of area for each mile of railroad. Or, reasoning inversely, Virginia has 0.085 mile of railroad for each square mile, and France 0.116 mile of railroad for each square mile of territory. Virginia has 483.29 inhabitants for each mile of railroad, and France has a population of 1,586.53 to each mile of railroad; or Virginia has 10.92 feet of railway to each inhabitant, and France 3.32 feet to each inhabitant. Thus it is seen that France, with a little more than five times the area of Virginia, has about twenty-three times the total population of the latter—a little less than five times the population per square mile; but, when we compare area with railway mileage, it is found that Virginia has only 3.22 square miles per mile of railroad in excess of France.

While, under the conditions of population in the two countries, the

last comparison seems anomalous, we will not need to seek far for the solution. When we consider that France is credited with 130,000 miles of macadam or stone highways, as against 689 miles for Virginia, we can appreciate the facilities of transportation possessed in that country outside of its railroads. Thus we would have for France 1.57 square miles of area for each mile of macadam road; and for Virginia 58.23 square miles for each mile of such road.

Again, a comparison of the population of the two countries with the mileage of macadam roads shows 293.27 inhabitants for each mile of macadam road in France, and 2,403.45 inhabitants for each mile in Virginia.

The French nation has certainly given the world assurance of what may be done in the construction and maintenance of highways, and the thrift and prosperity of those people stand as an everlasting monument to their efforts in this direction.

I am well aware of the probable opposition in this State to any plan that carries with it an increase of taxation. Since that eventful night on the 16th of December, 1773, when the partisans of old Samuel Adams went down to Boston Harbor and cast overboard the cargoes of tea, because tea meant taxation, the average American has had a most decided distaste for any visible form of taxation. He prefers to take his taxes like the child takes his medicine—disguised by aromatic essences, sweets and tinctures. He is, in fact, a species of sentimental ostrich, happy with his head in the sand, glorying in the homely saying, "Where ignorance is bliss, 'tis folly to be wise."

Forty years ago little or nothing was known of the pathology of germ diseases. Bacilli and bacteria were unknown. The physician struck out wildly and impotently, fighting a recognized malignant, deadly force, with no knowledge of its nature, and no power to resist its effects. And so it is with us. We are battling against an irresistible force in the shape of an invisible but not unfelt taxation, and we are calmly taking our rest in the shade of this deadly upas tree, oblivious of its noxious exhalations. We are annually paying a tribute to our bad roads, more onerous in its nature and more certain in its exaction than the oppression which incited Americans to rise and declare themselves free men. Shall we, who proudly refused to be the minions of government, remain forever the slaves of conditions, fettered with the shackles of our own inaction, and trammled by the delusion of our hopes?

We plead poverty and inability to raise money for the betterment of our roads, and we have been annually expending, in money or labor, an amount which, under skillful and trained direction, would have placed our common roads upon a plane where at least they would not have been a reproach to our civilization.

As near as I can ascertain, there was expended in labor and money on roads in Virginia in the year 1893 an amount approximating \$600,000. So it can be readily seen that we are maintaining our own roads at immense expense, a very small proportion of this money and labor being used in the construction of permanent highways. The treatment may be said to be entirely palliative. Our roads are no better than they were the year before, and year after year this patchwork goes on with few permanent results.

Now, let us assume that during the past twenty years \$300,000, had been spent on permanent improvement each year, and that the average cost of this work had been \$1,250 per mile, we would have to-day 4,800 miles of permanent road, or 48 miles to each county in the State.

It is stated on good authority, that in Union County, N. J., by reason of the improved system of road construction and maintenance, farming lands are estimated at an average of \$206 per acre, as against the average value of \$65 per acre for the entire State.

It is not necessary that we should take such an example as that to show what we are paying for our miserable roads, but from very conservative figuring it can be demonstrated that we are paying enough to build and maintain a thorough system of highways throughout the State.

The assessed value of land in Virginia for the year 1893 amounted to \$126,990,053. Now, it is certainly reasonable to assume that those values would be increased by not less than 20 per cent. with a good system of roads, which would give an increase in value of \$25,398,010.60, interest on which, at 6 per cent., amounts to \$1,523,880.63. Now, that amount of interest represents the increment of a value we should possess under the desired conditions, and is, therefore, an annual charge against the State on account of bad roads.

I have figured, from the Statistical Abstract of the United States for 1893, that our principal crops of corn, wheat, potatoes, and tobacco amount to 1,265,782 tons of 2,000 pounds. I omit all other products, as lumber, mineral, and other crops, as an offset against that part of the crops which may be consumed at home, and taking 2,000 pounds as an average load and 10 miles as the average haul, we have 12,657,820 ton-miles, which, at 25 cents per ton-mile, represents \$3,164,455 as the total cost of hauling all products to railroad or market. Now if, under the proposed conditions of good highways, the average load can be increased to even 4,000 pounds, then we are again paying each year \$1,582,227.50 for our bad roads. But if we can haul the load of 4,000 pounds in four-fifths of the time required to haul the load of 2,000 pounds on the unimproved road, then we effect a saving in cost of \$612,891, and that amount must be charged to the account of bad roads.

Then, taking the assessed value of all vehicles in the State at \$3,051,783, and estimating annual depreciation under present conditions at 10 per cent., it is perfectly reasonable to assume that under the proposed condition 5 per cent. would cover depreciation, thus giving another charge of \$151,586.90.

And finally, taking the assessed value of horses and mules at \$13,495,932, and allowing that with good roads we can reduce the present cost of feeding and depreciation of stock to an extent represented by 3 per cent. of value, we have \$404,877.96. Then we may sum up the annual cost of bad roads in Virginia as follows:

To interest on depreciation of land	\$1,523,880 63
To additional cost of hauling	1,582,227 50
To loss of time in hauling	612,891 00
To depreciation of vehicles	151,586 90
To depreciation of horses and mules	404,877 96
Chargeable to bad roads	<u>\$4,275,463 99</u>

Professor Eley has estimated that the loss per horse per annum on account of bad roads, amounts, in the United States, to \$15, and, figuring on that basis for the State of Virginia, we would have 290,567 horses at \$15, or \$4,358,505, as the cost of bad roads, or \$14.78 for each horse instead of \$15. I thought his figures too high until I made these calculations, but I am now convinced that they are perfectly reasonable.

If my reasoning on this subject of the cost of bad roads is correct, we are losing in this State \$11,713.60 for each day in the year, or \$2.58 per annum for each unit of population. If we had the use of the money chargeable to bad roads, we could construct 1,710 miles of the best class of macadam roads each year, and in fifteen years our road system would be on a plane with that of France.

According to these figures, our bad roads are costing us \$2,478,918.97, more than the total tax collected in the State, which, in 1893, amounted only to \$1,996,545.02, or, considering the total taxable values of the State for 1893, we are paying a little more than 1.068 per cent. on that amount.

This invisible but insidious tax is none the less fatal to our prosperity because it is not gathered by the tax collector. On its list there are no delinquents, and there can be no evasion of payment. It reaches every class, creed and condition.

When the Roman emperors built thousands of miles of their magnificent highways all over Europe, they were conferring a priceless boon upon unborn nations, but they were, in fact, simply emerging from conditions which threatened to destroy their empire and extinguish their greatness. But, nevertheless, those roads remain to-day as exam-

ples of the highest art in highway construction, and the pretorian roads, that echoed to the tread of Cæsar's legions, now resound under the wheels of modern ordnance.

It is a sad travesty upon our nineteenth century civilization that here in Virginia, the mother of States, where thousands of miles of difficult railroads have been located and built, requiring the best skill of the engineer and the unstinted treasure of the capitalist, the locus of the first practical system of electric railway, a world teacher in the art of tunnel construction, with geographic, geological and climatic conditions supplemented by unparalleled economic resources, we are still in the very infancy of the art of building and maintaining our public highways.

"Though the mills of God grind slowly, yet they grind exceeding small;" and so, with the accumulated grist of our four hundred years, gained under the nether stone of experience, we are ready to rise, and, with the same spirit which prompted our forefathers to wrest from King John the great charter of human liberty, we are to-day prepared to set about the establishment of that equilibrium in our system of internal improvement which is no less essential in political than in natural economy. It is in evidence, and attested to-day by the presence of representative men from every part of this broad commonwealth, that the term of our bondage is closing and the day-star of a brighter era has appeared.

I am filled with faith as to the result of the work of this Convention. It is the first time in the history of our State that such an assemblage, for such a purpose, has ever been convoked, and it has come to pass as a necessity born of conditions. I know my people and I honor their history and traditions, which teach me that when once they have determined upon the accomplishment of a purpose there is no looking backward until the goal is reached.

Through me, their unworthy representative, and my worthy colleagues, the Association of Engineers of Virginia sends you greetings and Godspeed in the great work you have undertaken, and I know that this Convention, carrying with it the good wishes of every Virginian who loves his State, will address itself to the task of reform in road laws with a resolute determination that recognizes no such word as "fail."

PORTLAND CEMENT CONCRETE AT FORT POINT.

BY GEORGE H. MENDELL, MEMBER OF THE TECHNICAL SOCIETY OF THE
PACIFIC COAST.

[Read May 4, 1894.*]

THE following notes and remarks result from recent experience in construction of fortifications in concrete, near Fort Point, in this harbor. They necessarily have a local flavor, and for this reason—and as affording examples of the cost of a particular kind of work in our neighborhood—it is hoped that they may possess some interest.

Concrete is a hackneyed subject about which it may be thought that little can be said that has not been said before. Yet it is always interesting by its varieties of fabrication and application, and is not at once exhaustible. Moreover, there is always something suggestive in accounts of local operations kindred to those in which we are or have been engaged.

Concrete is an agglomeration of the commonest fragments of stone and sand converted into a monolith by addition of water mixed with other common things, namely, impure clay and carbonate of lime, calcined and pulverized. The cementing material has the special quality of hardening in water, from which it derives its name—hydraulic cement.

These materials, mixed in due proportions, shortly become a solid mass, which grows in hardness and strength for months. This is concrete. It has a wide application and usefulness. It is the pavement under our feet, the foundation or walls of the house in which we live, the arch or lintel which covers our heads, the reservoir which impounds the water supply, the dam which directs or divides a river, the break-water which withstands the blows of the waves. It bears steady loads of 10 tons or more per square foot, and 200 tons or more per square foot are required to crush it. The rupturing or tensile strain may be 100 or more pounds per square inch. These powers of resistance, both compressive and tensile, vary with the character and proportions of the ingredients, and they may be adjusted to the requirements of any special construction.

The art of compounding the ingredients is simple, and may soon be learned by men of ordinary intelligence. The ingredients, so far as they are natural, are found everywhere, and wherever found they are com-

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mon and cheap. The artificial ingredient, the least in quantity—namely, cement—is comparatively costly, and for this reason it needs to be used with judgment and discretion, not too lavishly.

When we take account of the many varieties of sand and stone in the world, ranged by mineralogical composition or physical qualities of form, size, weight and hardness, and the differences in cement due to process of manufacture and character of ingredients, and reflect that every variation in material or process of manufacture leaves its mark upon the final product, we see that concrete is not one but legion.

Even here, with a limited range of variety in materials, the term is common to many products which vary much in cost, value, strength and applicability.

It is an important part of professional knowledge and judgment to select from these possible concretes the one that is best adapted for the construction in hand. We may say the best and the cheapest, for the engineer is bound to do his work economically. He must not use ten-dollar concrete in applications where six-dollar concrete would do as well or better. It is not paradoxical to say that a meagre concrete is, for some purposes, better than a more costly product richer in cement.

This matter touches the ethics of the engineer's profession. We are bound to do work well, and are also bound to do it as economically as possible. A mistake of too costly construction, made by an engineer of experience, may be likened to a misdemeanor in law, or worse.

The desire to make the work certainly good enough, naturally suggests liberal use of cement. There are circumstances where free use of cement is judicious and necessary; but in many cases the builder may find reward and economy in a careful study of materials in their bearing upon the cost of masonry.

There are standing at the door of the office, at the Fort Point Works, two blocks of concrete of Portland cement, the matrix being one cement to five sand. These blocks are samples of a cheap and fair concrete, about two cubic yards to a barrel of cement. It weighed 148 pounds to the cubic foot when three months old, which is more than the weight of a richer product. In a construction where weight is particularly required, and where there is no great strain, and plenty of time to strengthen, this character of concrete might be as fit as a richer compound.

The quality of concrete is generally defined by the proportions in volume of the solid ingredients, the cement being taken as unity. When a barrel of cement is taken as the unit, there is danger of confusion of ideas, for the reason that a barrel may be taken to mean either one of several volumes. The cubical contents of a barrel of Portland cement have been found to vary from about $3\frac{1}{4}$ to about $3\frac{1}{2}$ cubic feet. The cement is packed more or less closely by different makers. The gross

weight is found to be, with a little variation, 400 pounds; the net weight about 375 pounds per barrel. When poured out loosely on a platform, and measured by means of a cubical box, not shaken, the contents of a barrel make about $4\frac{1}{2}$ cubic feet. Converted into a paste by addition of about two cubic feet of water, the volume becomes about four cubic feet.

If we take a formula for our mortar of any given proportion of sand, say three volumes to one, the amount of sand for a barrel of cement may be about 10, or 12, or $13\frac{1}{2}$ cubic feet, accordingly as we take the volume of a barrel of cement to be $3\frac{1}{2}$ —as it is when compacted—or 4 feet in paste, or $4\frac{1}{2}$ feet in loose volume. The clearest formula is expressed in a given number of cubic feet, both of sand and rock, to a barrel of cement.

The volume of paste is the best, we may say the scientific, unit, but it may be either of the three under the condition that it be defined. In the operations at Fort Point three parts of sand are understood to be $13\frac{1}{2}$ cubic feet per barrel of cement. Thus understood, the proportions of one cement, three of sand, and eight of rock and gravel, which constituted the formula usually employed, gave a volume of concrete in place about equal to the volume of the stone used, that is, for one barrel of cement, 36 cubic feet of concrete, or $1\frac{1}{3}$ cubic yards.

The quantity of water required with dry materials is about four cubic feet per barrel of cement. The rule is to mix the concrete with a minimum of water, and to tamp it until water gathers on the surface. In hot, sultry days, the evaporation being rapid, it was found necessary to mix with more water. The stone used was quarried at Angel Island, in sizes suitable for a "Gates" crusher, delivered on the wharf at Fort Point, hauled in wagons to the crusher, which delivered it to the mixer, into which all the ingredients were fed automatically. The mixing was continuous. The concrete was delivered, at the mouth of the revolving cylindrical mixer, into cars holding twenty cubic feet. When a car was filled, the door of the mixer was closed for a minute, during which a second car was put in place, and during this minute the concrete accumulated in the mixer.

This continuous mixer has obvious advantages, but there is difficulty in automatically delivering materials in stated proportions. The original arrangement of the supply hoppers was modified, and bettered, as a result of our experience, so that at last the desired result was measurably attained.

The cost of concrete per cubic yard, in place, distributed among the ingredients was, when made in mixer, as follows:

Portland cement	\$1 82
Stone.	1 40
Gravel	35
Sand	29
Water	4
Crushing, mixing, transporting and ramming.	80
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Total	\$4 70

The cars were pushed by two men to the place of deposit, a variable distance of 100 to 200 yards, and discharged from a tramway through a height which was 30 or more feet at the beginning, diminishing to 3 or 4 feet at the close. The concrete was then shovelled into wheelbarrows, and wheeled 20 to 40 feet. The structure is a great mass, being about 60 feet long, 40 feet wide, and 30 feet in height.

The following is a record of several weeks of work :

MATERIALS USED.

Broken stone	1,500 cubic yards
Gravel	475 "
Sand	572 "
Portland cement, 1317 barrels	220 "
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Total	2,767 cubic yards.

Volume of concrete measured by cars of 20 feet capacity, 2,433 cubic yards. Volume compacted, 1,825 cubic yards.

A car-load of 20 feet of loose concrete was found, in different experiments, to make 15 to 15½ cubic feet, compacted. The quantity of compacted concrete, 1,825 cubic yards, is practically two-thirds of the loose volumes, namely: 2,767 cubic yards. No account of water is taken here.

Gravel and sand are, to some extent, interchangeable, so far as sizes are concerned, and, to bring the results just given into relation with the formula, we need to class about 100 yards of gravel, more or less, as sand.

The cost given—namely, \$4.70 per yard—includes no charge for timbering, or for incidental expenses, other than the pay of the foreman and the men directly employed. The day is eight hours, the pay of foreman \$4.00 per day, and of the men \$2.00. Cement cost \$2.50. The empty barrels furnished fuel.

Another example of concrete, placed in smaller masses—under very different circumstances—is found in the piers of the steel bridge at Alameda.

The cement was furnished in this city to the contractor, who had no pecuniary interest or risk in it, except to transport and care for it. The

cost of cement was \$2.93 per barrel. The quantity of concrete distributed in five piers was 2,352 cubic yards, consuming 1,940 barrels of Portland cement. One barrel gave 1.2 cubic yards in place. The contractor was paid \$4.90 per cubic yard for making and placing concrete, and supplying all labor and materials, except cement. The cost of the concrete to the United States, including service of an inspector, was \$7.36 per cubic yard. A continuous mixer was used.

The following accounts of experiments are in our records:

FIRST CASE.

1 barrel of Portland cement, measured loose	4 $\frac{5}{12}$ cubic feet.
Water added	2 "
Volume of stiff paste resulting.	4 "
Moist sand of medium coarseness added	10 $\frac{1}{3}$ "
Water added	2 "
Volume of quite wet mortar resulting	9 $\frac{1}{8}$ "
Gravel, sizes $\frac{3}{4}$ " and less, added	36 $\frac{1}{2}$ "
Amount of loose concrete.. . . .	45 $\frac{1}{4}$ "
Amount tamped in place	37 $\frac{1}{2}$ "

Remark :—There seems to be a suspicion of error in the volume of mortar, to the extent of one measure—a cubic foot box. Volume of mortar perhaps ought to be 10 $\frac{1}{8}$ instead of 9 $\frac{1}{8}$.

SECOND CASE.

1 barrel of cement, loosely measured.	4.58 cubic feet.
Water	1.75 "
Volume of paste	3.8 "
Sand 3 volumes of paste.	11.4 "
Water	2.5 "
Volume of mortar,	12.3 "
Gravel, in sizes of beans and smaller	36.9 "
Volume of loose concrete.	43.23 "
Tamped volume not measured.	

THIRD CASE. BARREL OF 3 $\frac{1}{2}$ CUBIC FEET.

Volume of loose cement	4 $\frac{1}{2}$ cubic feet.
Water	1 $\frac{1}{2}$ "
Volume of paste.	3 $\frac{3}{8}$ "
Sand	13 $\frac{1}{2}$ "
Water	2 "
Volume of mortar	14 "

REMARKS.

The varieties in forms and sizes of materials are so great, and personal equations are so different, that rules as to quantities to result from combinations of materials in different proportions, can not be made precise. Each person is apt to find the rules derived from his own experience to differ from those established by others. Measurements of materials vary

with the manner of making them. The writer has chosen to make all measurements loose—that is, the vessels are not shaken to settle the materials to a smaller volume.

Moreover, the void spaces, howsoever the measurements be made, vary with the sizes and variation in sizes. This is illustrated in the first case, in which the voids in $36\frac{1}{2}$ cubic feet of gravel are more than filled with $9\frac{1}{8}$ or $10\frac{1}{8}$ (if the latter be correct) of mortar. Ordinarily, voids are 33 to 40 per cent. In this case they amount to about 25 per cent., and are accounted for by the fact of variation in sizes from $\frac{3}{4}$ -inch to that of bird shot.

The advantage of graded sizes in broken stone is clearly shown. The voids being thereby reduced, a given quantity of mortar will take more stone and make more concrete.

According to the experience of the writer, a matrix of 10 feet of loose sand to 1 barrel of Portland cement will suffice for about 27 feet of suitable broken stone, and will make about 1 yard of concrete in place. If we use 13 to 14 feet of sand we can make $1\frac{1}{2}$ cubic yards of concrete to a barrel. With 22 feet of sand we ought to get about 2 yards to a barrel.

CHARACTERISTICS OF CEMENTS.

Particular care was had in selecting the sand used in this work. It is believed to be the best that can be conveniently obtained for concrete. It is coarse, running into gravel, mixed with fine—clean and sharp. It was collected on the beaches adjacent to Fort Point.

The usual tests for tensile strength, by breakage of briquettes, made neat of salt and fresh water, and with different doses of sand, of ages from 1 to 7–28 days, and varying to a year, were kept up during the progress of the work, and recorded.

The tensile record, particularly with neat briquettes, is good for all cements used. The tests of briquettes dosed with sand, seem to be more discriminating than with neat briquettes. It is observed that while two cements gauged neat may not show great differences in tensile strength, yet notable variations appear when gauged with sand, the fine ground cements showing greater strength than the coarser.

The sieves used for determining fineness were bought in this city. They are graded by the maker as 50–70–100 to the lineal inch. In fact the first two contain respectively about 2,250 and 4,200 meshes to the square inch. They are referred to in this paper under the maker's grades. The meshes in the third could not be conveniently counted.

The sieves being arranged in column, the coarsest on top and the finest on the bottom, a charge of 1,000 grains of cement is placed in the upper sieve, and all are duly shaken. This operation completed, you

have 4 portions graded in order of fineness, which are then separately weighed.

The annexed table represents the mean results of several tests with each of six brands of cement of good standing.

TABLE.

Cements.	Passed 50.	Passed 70.	Passed 100.
No. 1	980	953	869
" 2	929	844	736
" 3	989	948	833
" 4	925	863	771
" 5	969	895	764
" 6	927	873	788

The sieve wires are respectively Nos. 35, 37 and 40, American gauge.

The respective mesh areas of the 50 and 70 sieves, so-called, are approximately 3,600 and 8,500 to the square inch.

If there were 100 meshes to the inch in the 100-sieve, the mesh area would be 21,000 to the square inch.

There is some ground to think that the mesh area of this sieve is not far from 17,000 to the square inch.

The portion of one of the fine ground brands which passed the 100 sieve, was made with three parts of sand, by weight, into eight briquettes, and broken at ages of 127 to 129 days. The tensile strength per square inch varied between a minimum of 387 pounds to a maximum of 442, with an average of 417 pounds. The same cement, ungraded, with three parts of sand, 120 days old, gave a mean of 333 with thirty briquettes. The portion which, having passed the 70 sieve, was refused by the 100 sieve, was similarly dosed with sand and made into four briquettes, which broke at 127 days with strain per square inch of 57 pounds—65—75. The fourth briquette broke without strain. The portion which, having passed the 50 sieve, was refused by the 70, treated in five briquettes at the same age, broke at 48 to 58 pounds. Three briquettes, with three parts of sand, left in moulds thirty hours, broke on removal or fell apart when placed in water.

This experiment suggests, so far as it goes, that in the usual applications with sand, the valuable part of cement is found in the finest grains. The next grade in fineness shows little comparative strength, the next still less, and the coarsest none at all. Yet the coarsest grains, when sufficiently pulverized, develop hydraulicity. It remains to determine whether or not time can add value to the coarser grains. A sample was recently sent for test, which is represented to be a finer grinding of one of the coarse brands of the table, to about the scale of the finest. It showed great improvement in strength by finer grinding.

The writer received from a manufacturer on the continent of Europe the following statement, which is here given for what it is worth:

"Dividing Portland cement into four grades of fineness, by sieves of 324-900 and 5,000 meshes to the square centimeter, which correspond to 2,100, 5,800 and 32,000 to the square inch, it is found that while the finest, No. 4, is most active, yet No. 3 will equal it in strength in reasonable time; No. 2 will, after a year in water, form a compact mass, with, however, no great power of resistance. No. 1 will always remain inert."

According to this rule, the best examples found here show at least 5 per cent. of useless grains, while some brands show 15 per cent., or more.

It is claimed for finely ground cements that they take more sand. This means that a less proportion of cement to sand will give an equally good mortar.

Assuming, for the purpose of illustration, the numbers already quoted, namely, 417 pounds for sifted and 333 pounds for unsifted, to express the relations between these samples, it would appear that the first, with five parts of sand, and the second, with four parts, would produce mortars of equivalent tension. So far as this goes, the value of the first cement is about one-fourth more than that of the second. Without insisting upon the exactness of this deduction, we may at least see that a builder can afford to pay something for fineness.

It was found that while very fine ground cement gave the best results when mixed with sand, yet a neat briquette made of the finest ground part of a cement is, at least at some ages, not generally so strong to resist tension as a neat briquette made of the same cement ungraded.

A notable difference is observable in the quality of packing and the soundness of barrels in which cement is imported. A good barrel suggests good contents. Bad barrels involve loss both in cooerage and in the quality of the cement. As a general rule, a preference is to be given to the best packages. The best are tongued and grooved.

It is to be said, for all the standard brands known to the writer, that no indication of free or uncombined lime has been detected in any of them.

HAND-MADE CONCRETE.

Much the greater part of the concrete was made in a mixer, yet a considerable quantity was mixed by hand. During August, 1892, a gang of twenty men was employed, under a foreman, in hand mixing. The foreman received \$4.00 per day, and the men \$2.00 for eight hours.

The average daily output was 45 cubic yards, and the cost almost exactly \$1.00 per yard for labor of mixing and placing. The work was done in batches of 4 barrels of cement, and 144 cubic feet of broken rock and gravel, giving the same amount of compacted concrete.

The manner of making was this, namely : The materials were grouped in the most convenient manner about a large platform of plank, upon which the mixing was done. Upon this platform the stone and gravel, measured in wheelbarrows, were placed in a stratum of even thickness. Upon this sand was wheeled, and leveled with a straight-edge. The cement, also leveled, formed the top stratum. Water was added in the turning. The materials were turned twice, and carefully dispersed in the act of turning, which is important. A third turning resulted from shoveling into wheelbarrows, and a fourth in its distribution over the building. The mass of the building was large. There was no ascent in wheeling, and the distances were short.

The men were a picked lot—a sort of evolution from a great number of laborers; and, taken altogether, the circumstances were exceptionally favorable.

It will be remembered that the labor cost of making by machine and placing has been given at 80 cents, which included crushing rock. Making allowance for the cost of crushing, the result of comparison of machine and hand making, the latter under the most favorable circumstances, gives the result that hand-made costs about 50 per cent. more than machine made, in the item of labor.

Doubtless, under average conditions the comparison would be more favorable to the mixer.

The weight of concrete three months old, as made at Fort Point, is 143 pounds per cubic foot.

REGULATIONS GOVERNING THE ERECTION OF BUILDINGS, APPLICABLE TO CITIES HAVING A POPULATION OF FROM 10,000 TO 30,000.

COMPILED BY THE ASSOCIATION OF ENGINEERS OF VIRGINIA.

Approved and adopted June 23, 1894, by the City of Roanoke, Va.

1. *Be it ordained by the Common Council for the City of Roanoke.* That before the erection, construction, alteration or extension of any building or part thereof in the city is begun, the owner, builder, or architect shall submit to the City Engineer a clear statement of the material to be used and the mode of construction of the proposed building or alteration, with the plans and specifications, said statement to be in writing on suitable blanks to be furnished by the City Engineer for that purpose, and no building or part thereof, alteration or extension shall be commenced until the owner or builder shall have received from the City Engineer a certificate of permit specifying the material of which the outer walls and outer covering of the roof of said building is to be composed, the street upon which and the distance therefrom at which said building is to be placed, a copy of which shall be filed in the office of the City Engineer under the date of its issue, and said permit shall be issued by the City Engineer after examination of the plans and specifications or detailed description; provided they are in conformity with this ordinance. If a building or alteration or extension of a building shall be begun without said certificate of permit, the builder and owner shall both be deemed to have violated this ordinance.

2. It shall be the duty of the said City Engineer to examine the condition of all buildings undergoing alteration or being erected within the city limits, and to serve notice in writing upon both the contractors and builders and upon the owners or architects of such structures as he may deem to be unsafe and insecure by reason of the mode or manner of construction, or the material used in the construction thereof, and shall order such changes in the mode or manner of construction as he shall deem necessary for public safety.

3. The said City Engineer is hereby empowered, whenever in his judgment occasion may require, to enter into and upon any building, premises, staging or other structure, for the purpose of examining the same with reference to its safety and of attending to the performance of his duties as required by law.

4. Any wooden building already constructed in the fire limits, which may hereafter be damaged, may be repaired, provided, the build-

ing was a good sound one previous to said damage, and provided, that it is not more than half destroyed, exclusive of the foundation. The City Engineer shall determine the amount and extent of such damage.

5. The City Engineer may permit temporary wooden structures in connection with the erection of buildings; said permit to be given in writing for a specified time.

DEFINITIONS.

6. In this ordinance the following terms shall have the meanings respectively assigned to them :

By the term "City Engineer," is meant such officer or officers as is designated by the City Charter or general ordinances of the city to inspect the erection of buildings.

7. "Alteration" means any change or addition.

8. "Cellar" means a lower story, of which one-half or more of the height from the floor to the ceiling is below the level of the ground adjoining.

9. "Foundation" means that portion of a wall below the level of the street curb; and where the wall is not on a street, that portion of the wall below the level of the highest ground next to the wall; but, if under party or partition walls, may be construed by the City Engineer to mean that portion below the cellar floor.

10. "Party wall" means every wall used, or built in order to be used, as a separation of two or more buildings.

11. "External wall" means every outer wall or vertical enclosure of a building other than a party wall.

12. "Partition wall" means any interior wall or masonry in a building.

13. "Partition" means any interior wall in a building other than a partition wall.

14. "Repairs" means a reconstruction or renewal of any existing part of a building by which the strength is not reduced nor the fire risk increased, and which, in the opinion of the City Engineer, is not made for the purpose of converting the building, in whole or in part, substantially into a new one.

15. "Thickness of a wall" means the minimum general thickness of such wall.

16. "Stories" are counted from the first tier of beams at or above the level of adjoining ground or sidewalk.

17. "Half story" means that portion of a story immediately under the roof, whose greatest inside height shall not exceed five feet from the floor to the spring of the roof.

18. "Wooden building" (within the fire limits) means any building any structural part of whose outside wall is of wood.

19. "Wooden building" (outside the fire limits) means that portion of any building which has a wooden exterior.

20. "Building of brick or other incombustible material" means any building the structural part of whose outside wall is of such materials.

21. "Block of dwellings" means a series of two or more houses used mainly for dwellings, such houses being separated by partition walls and having separate entrances and stairways.

22. "Shed" means a structure not exceeding one story in height, at least one of whose sides shall be open.

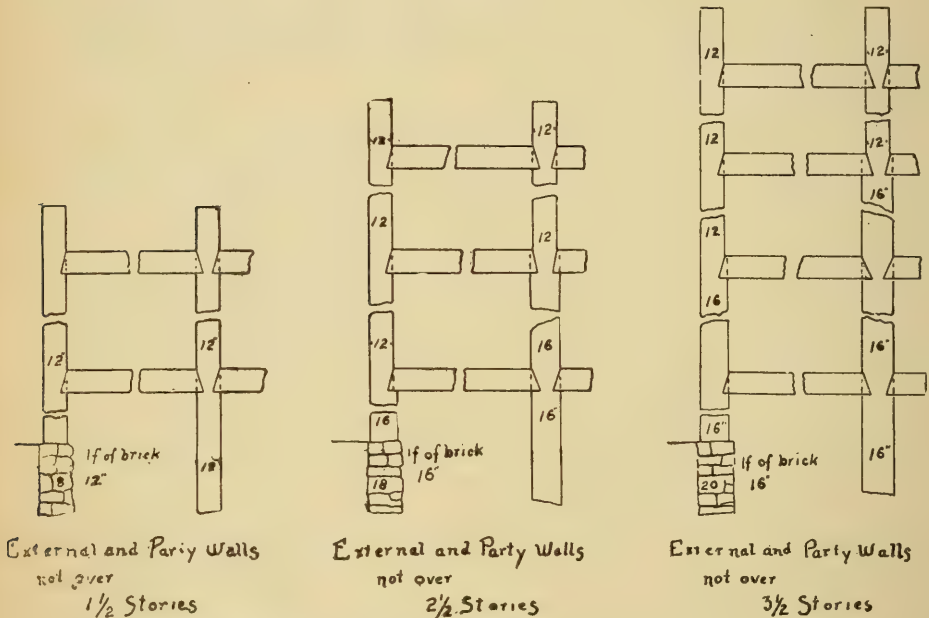


PLATE 1a.—BRICK BUILDINGS OTHER THAN DWELLINGS.

23. "Cement mortar" means a mortar composed of good, fresh cement, and clean, sharp sand. When deemed advisable, a small amount of lime may be used, not, however, exceeding the quantity of cement. When used in foundations the amount of lime must not exceed one-fourth the quantity of cement.

WALLS OF BRICK BUILDINGS.

24. The thickness of walls shall not be less than is indicated by the diagram on Plate I. The maximum load which shall be allowed on any foundation or masonry shall be as follows: Earth foundations, three tons per square foot; rock, ten tons per square foot; concrete, ten tons

per square foot; common rubble, four tons per square foot; first-class rubble, ten tons per square foot; block stone, twenty-five tons per square foot; common brick and lime, six tons per square foot; common brick in cement, ten tons per square foot; pressed brick in cement, fifteen tons per square foot.

25. All walls over one hundred feet in length without cross-walls or buttresses shall be increased four inches in thickness.

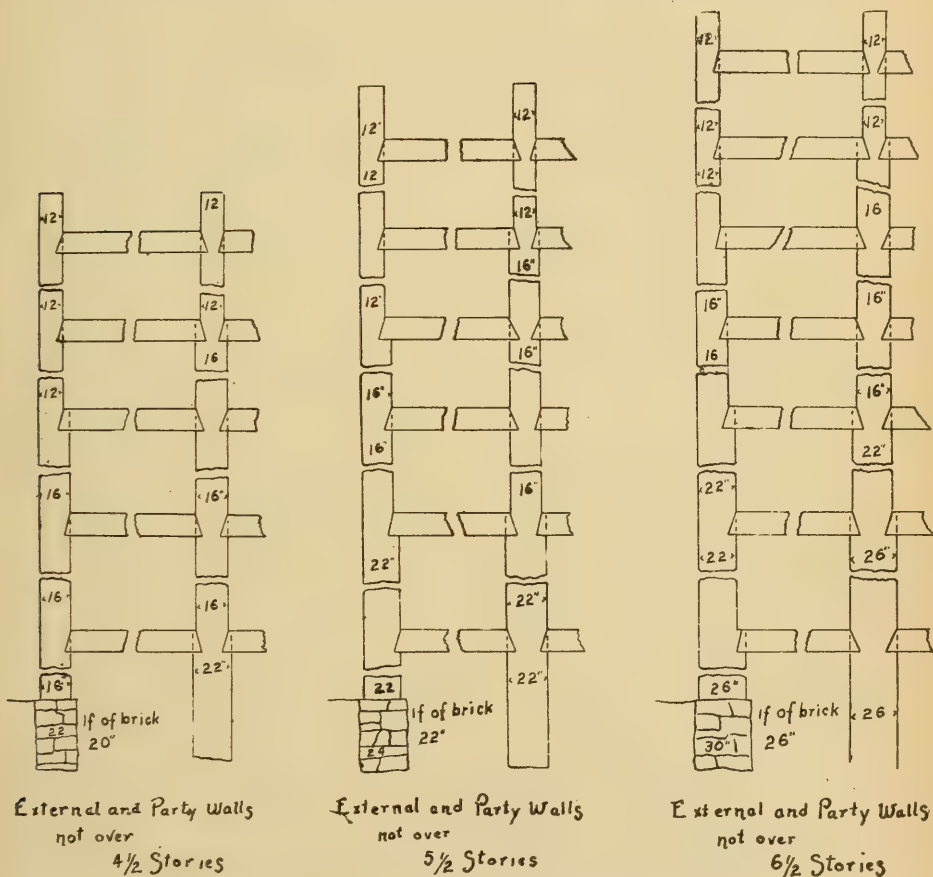


PLATE 1b.—BRICK BUILDINGS OTHER THAN DWELLINGS.

26. When hollow walls are used, the air spaces are not to be included in the thickness required.

27. Slots and chases in the walls shall not be allowed to come within four inches of the opposite side of the wall, and no two slots shall be within eight feet of each other.

28. The walls of all brick buildings over three and one-half stories

in height shall be well laid in cement mortar. All other brick walls shall be well laid in the same or in some other suitable mortar.

29. If any brick building already built, or which may hereafter be built, shall be enlarged, raised or built upon, it shall be made to conform to the requirements of this ordinance.

30. Whenever more than half the area of any brick wall is occupied by window or other openings, the constructive framework and casings (except ordinary window frames) of said openings shall be of iron or other incombustible material, and the remaining portions of the wall shall be suitably thickened.

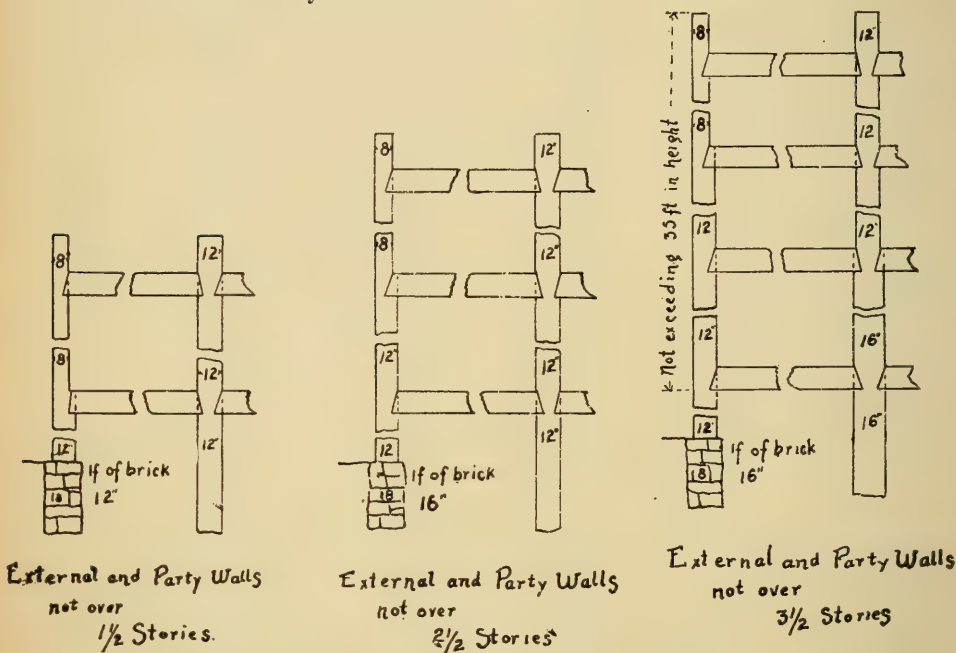


PLATE 1c.—WALLS OF BRICK DWELLINGS.

31. No wood lintels or beams of over six-foot span shall be used to support brick or masonry walls.

32. No brick or stone wall of any description shall be carried on wooden pillars.

33. All brick walls shall be well bonded at least every sixth course throughout the thickness of such walls.

ASHLAR FACING STONE.

34. No ashlar shall be less than four inches thick, and shall have a bond stone running through the thickness of the wall at least once in

every square yard of surface of wall; and it shall not be considered a part of the wall when reckoning the thickness of walls as per paragraph on "Walls of Brick Buildings," unless it be eight inches or more in thickness, in which case all but four inches of its thickness may be reckoned as a part of the wall; provided, however, that in buildings used as dwellings only ashlar eight inches thick may be used in facing brick cellar walls above grade without bond stones.

FOUNDATIONS.

35. The thickness of foundation walls shall not be less than is indicated by the diagrams of such walls on Plate I. The diagrams are intended for ordinary conditions only. Whenever foundations are unusually deep or serve as retaining walls, etc., the thickness must be proportionately increased.

36. All foundation walls shall be properly bonded and well laid in cement mortar. Frame dwellings may have foundations laid in lime mortar.

37. Broad and heavy footing courses are to be provided wherever the condition of the soil or the height of the building may demand them, and in all cases brick foundations shall be started on such footing courses.

38. No wooden post shall be used in any cellar as a structural support. Brick piers shall have footing stones not less than six inches thick and projecting not less than six inches all around.

WALL ANCHORS.

39. The front, rear, side and party walls of any building hereafter to be erected shall be anchored to those adjoining every six feet of height by T anchors made of one and one-quarter inch by three-eighths of an inch wrought iron, except when said walls are carried up together and well united and bonded at the point of contact. The said anchors shall be built into the side or party walls not less than thirty inches, and into the front and rear walls within four inches of the outside of the front and rear walls, so as to secure the front and rear walls to the side, end or party walls. The front, rear, side and party walls shall be anchored to each tier of beams at intervals of not more than six feet apart (except in cases of mill construction, when each timber shall be well anchored), with some form of releasing anchor approved by the City Engineer.

CHIMNEYS AND SMOKE PIPES.

40. No chimney or smoke flue shall be built with less than eight-inch walls below the roof line unless lined with terra-cotta pipe. And

when not so lined, all interior joints shall be struck smooth, and no par-geting will be allowed. No chimney-top shall be less than four feet above the roof (for flat roof) nor below the ridge of any pitched roof, unless more than fifteen feet from same.

41. Flues in party walls shall not extend beyond the center of the wall. Joint flues in party walls shall be separated by four and one-half inches of brick work for their entire height.

42. No chimneys shall be started or built upon any wooden floor or beam, and in no case where the breast of chimneys shall project more than six inches shall it be commenced in any wall or supported by cor-belling, but shall be started from the foundation.

43. Flues for boilers and furnaces for manufacturing purposes shall be built of brick or metal of such size and height as may be determined by the City Engineer.

44. All hearths shall be supported by arches of stone or brick or by iron construction, and no chimney in buildings already erected or hereafter to be built, shall be cut off below and supported by wood, but shall be wholly supported by brick, stone, iron or steel. The back of no fireplace or grate shall be less than eight inches from the opposite side of the wall.

45. Depositories for ashes shall be built of brick or other fire-proof material.

46. In no building, whether the same be a frame building or other-wise, shall any wooden girders, beams, timbers or other wood-work be placed within six inches of any hot-air or other flue unless protected by brick, mineral, wool or their equivalent, in which case the distance may not be less than two inches, and in no case shall any timber or wood-work be built into the brick-work of any chimney or smoke flue, but shall be framed around same as in Section 55.

47. No smoke pipe in any building with wooden or combustible floors or ceilings shall hereafter enter any flue unless the said pipe shall be at least twelve inches from either the floors or ceilings or side parti-tions, and in all cases where smoke pipes pass through stud or wooden partitions of any kind, whether the same be plastered or not, they shall be guarded by either a double collar, made with terra-cotta on the out-side and metal on the inside, with at least one inch air space and holes for ventilation between, and extending through the partition; or by being enclosed by a terra-cotta thimble, with at least six inches of brick-work all around for full thickness of the studding; provided, however, that the City Engineer may allow a less distance than twelve inches from a smoke pipe to wood-work if the latter is protected by a shield of tin-plate or other suitable material not less than one inch from the pipe and two inches from the wood-work.

48. Whenever a smoke pipe passes through the floor it shall be encased with a double collar, as above specified, except that the collar shall be entirely open at the bottom and have holes only at the top.

49. Furnace smoke pipes shall not be less than eighteen inches from all wooden floors or partitions.

50. Tops of all furnaces shall not be less than ten inches from the floor joists above, and shall be covered with two inches of sand or otherwise protected.

STEAM BOILERS AND PIPES.

51. No high pressure steam boiler shall be set without a permit made out in due form by the City Engineer; and no such boiler shall be set inside or under any city or town building, any jail, schoolhouse, church, theatre or other place of public assembly, any hotel, office or apartment building without a special permit from the City Engineer, requiring annual inspection of the boiler by competent inspectors, reports of such inspections to be regularly filed with the City Engineer.

52. All steam pipes passing through wood-work shall be protected by an iron collar, with an air space between. All steam pipes shall be supported by iron brackets or hangers.

WOODEN FLOORS.

53. The size and spacing of floor joists, except for "mill construction," must be not less than provided for in the following table:

Span not more than	Least size.	Greatest distance on centers.	Least number rows of cross bridging.
12 feet	2 inches by 8 inches	16 inches	1
15 feet	2 inches by 10 inches	16 inches	1
18 feet	2 inches by 12 inches	16 inches	1
20 feet	2 inches by 14 inches	16 inches	2
20 feet	3 inches by 12 inches	16 inches	2
25 feet	2 inches by 14 inches	12 inches	3
25 feet	3 inches by 12 inches	12 inches	3

The maximum fibre strain which shall be allowed in any beam, joist, girder or tie shall be as follows: Rolled steel, 16,000 pounds per square inch; rolled iron, 12,000 pounds per square inch; cast iron, 5,000 pounds per square inch; yellow pine (Carolina or Georgia), 1,350 pounds per square inch; Virginia pine or spruce, 1,000 pounds per square inch; oak, 1,200 pounds per square inch.

54. In all cases the joists are to be doubled and spiked under partitions and around openings, and supported on suitable hangers, and are to be properly bridged; and where more than two stories of partitions come over a span, a suitable truss is to be formed.

55. In no building shall any wooden girders, beam or timbers be placed within one inch of the outside of any chimney or wall outside of any flue.

56. All wooden beams and other timbers in the party wall of every building hereafter to be erected or built of stone, brick or iron shall be separated from the beam entering in the opposite side of the wall by solid mason work of at least four inches.

57. The ends of all joists in the brick walls shall be so beveled that no level portion of the top of such joists shall enter into the brick-work. All joists shall rest at least four inches on the brick-work.

BRICK WALLS IN A BLOCK OF DWELLINGS.

58. Every dwelling in a block of dwellings shall be separated from the one adjoining by a brick party wall running from front to rear. Such walls shall be without openings, and shall be built out to boarding of sides, roof and cornice. The thickness of such walls shall be as specified in this ordinance.

WOODEN SILLS.

59. The sills of all wooden structures over one story in height shall be not less than 4 x 6 inches. The sills of all wooden structures which are set at a greater height than one story above grade shall be anchored to the brick-work below.

STUDDING.

60. The studding of outside walls of all wooden structures three stories in height shall be not less than 2 x 5 inches, set not more than sixteen inches on centers. And the studding of outside walls and bearing partitions in any wooden structures shall be not less than 2 x 4 inches, and set not more than sixteen inches on centers.

61. Every building 50 feet wide or over (other than a dwelling house occupied by not more than one family) shall have to each story above the first, two means of egress to the ground by suitable stairways, either inside or outside the building. And such stairways shall be kept free from obstruction at all times, and shall be accessible from each room in such story. The City Engineer may, however, except from this ruling fire-proof buildings, no parts of which are used for dwelling purposes. Wooden stairways shall be supported by horses not less than 2 x 12 inches, and not over eighteen inches on centers.

ELECTRIC WIRING.

62. Any electric wiring shall be in accordance with the specifications and requirements of the Southeastern Tariff Association.

REGULATIONS WITHIN FIRE LIMITS.

63. No building shall be erected within the fire limits unless the structural part of its walls be of brick, stone, iron or other incombustible material. Every interior iron column supporting masonry wall or pier must be fire-proofed by being properly encased in terra-cotta or other fire-proof material.

64. Every outside hollow frame wall and partition, every furred partition wall or outside furred wall of any building over two and one-half stories in height shall be provided with mortar, brick and mortar, or other suitable fire-stops at each story.

65. Plastering shall be carried down behind all bases.

66. Planking and sheathing of the roof of every building other than of wood, hereafter erected or built, shall in no case be extended across the party wall thereof, and every roof within the fire limits shall be covered with slate, tin, copper, iron or other incombustible material.

67. The party walls in all brick buildings shall be carried up at least one foot above the roof, and shall be capped with tile or other incombustible material.

68. Every cornice within the fire limits, except on isolated buildings used as dwellings only, shall be of brick, iron or other incombustible material, and where not of solid masonry, all brick or stone walls shall be carried up behind cornices to roof covering.

SAFETY APPLIANCES.

69. In all buildings of a public character already erected, or hereafter to be built, such as hotels, churches, theatres, schoolhouses, flats, restaurants, railroad depots, public halls or similar buildings, used or intended to be used for purposes of public amusement or instruction, the halls, doors, stairways, seats and aisles shall be so arranged as to facilitate egress in case of fire or accident, and to afford the requisite and proper accommodation for the public protection in such cases. All doors of exit leading from any assembly room where crowds do congregate, shall be so hinged as to open outward from the room or rooms.

70. It shall be the duty of the owner or owners of every building used or intended to be used as a hotel, factory, theatre, tenement house, seminary, college, academy, hospital, asylum, hall or place of amusement, and of the trustee or trustees of any estate, association, society or buildings as described above, which may have its upper floor thirty feet or more above the ground, used or intended to be used for any of the purposes above mentioned, to provide and cause to be erected and fixed to said building, iron fire-escapes of a pattern which shall be approved by the City Engineer, who shall also have the right to designate the position of said fire-escapes.

PLUMBING AND DRAINAGE OF BUILDINGS.

71. No person or corporation shall carry on the business of plumbing unless licensed as a plumber. Applications for such license shall be made to Council on blanks provided by the Clerk. Such applicant shall appear before the City Engineer, who shall subject him to a rigid verbal examination as to his competency and understanding of the City Ordinances, specifications, drawings and standards, referring to the plumbing of wastes, drains, laying of sewer connections, etc., and Council shall grant license to said applicant only after a written certificate has been sent to them by the City Engineer testifying to the competency and fitness of said applicant.

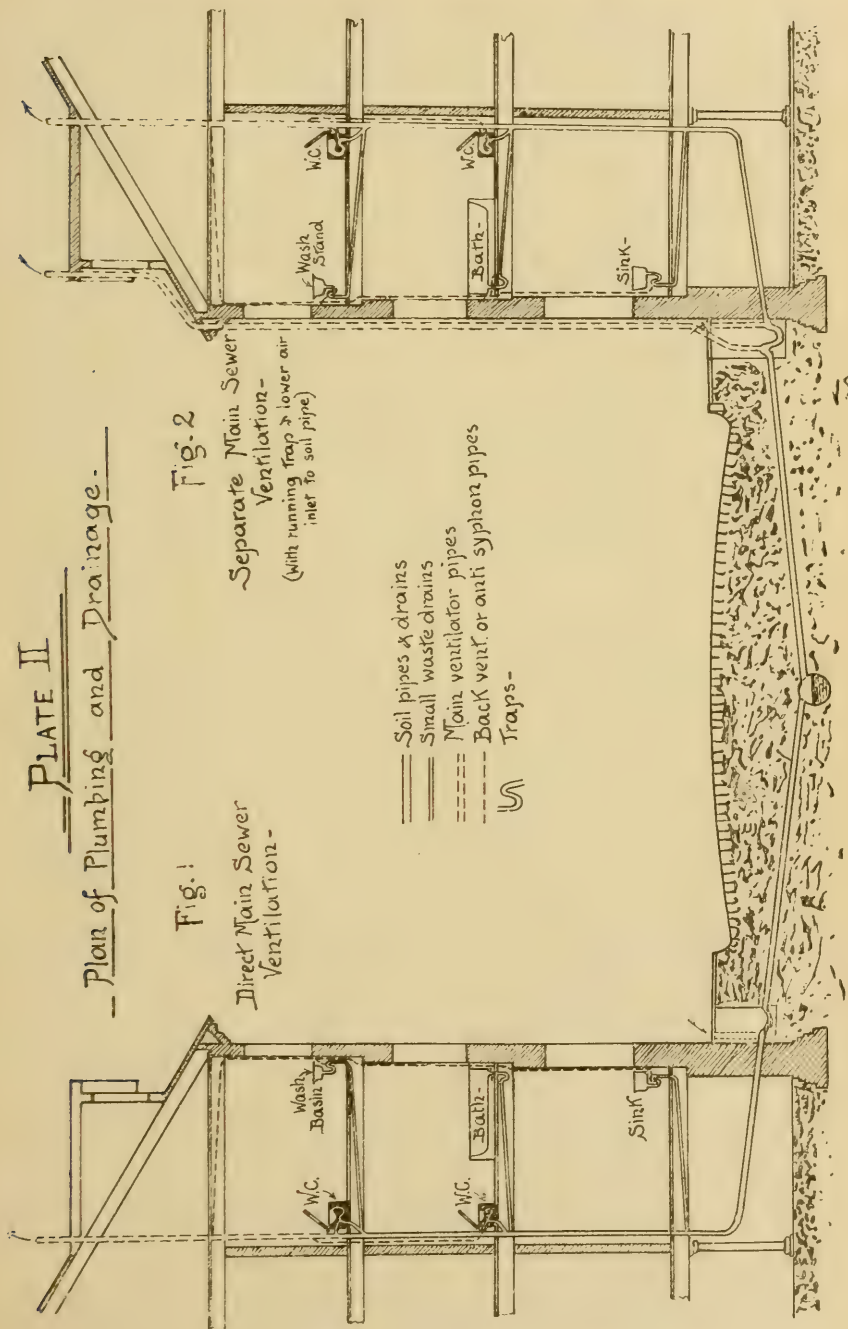
72. It shall be the duty of every registered plumber to give immediate notice of any change in his place of business, for correction of the register.

73. The drainage of all buildings, public and private, and the alteration to the same, shall be executed in accordance with plans and specifications previously approved in writing by the City Engineer, who will grant a regular permit for carrying on the work, and no plumbing or house drainage shall be proceeded with unless the permit is in the hands of the men doing the work.

74. There shall be a separate plan for each building, public or private, or any addition or alteration thereof, accompanied by the specifications or descriptions for all plumbing and house drainage of said building or buildings, prescribed and furnished for this purpose, showing the location, size and kind of pipe, the material to be used, traps, closets and fixtures; the said plans to be placed on file in the office of the City Engineer; said drawings, plans, specifications and descriptions to be furnished by the architect, builder or agent, where one is employed, otherwise by the owner or reputed owner. All applications for a change in plan must be made by the owner or reputed owner, architect, builder or authorized agent.

75. It shall be the duty of the said City Engineer to give immediate attention upon receiving any notice as hereinbefore specified, and within the time therein limited, to wit: three days to report thereon, and in case that the City Engineer shall find that any of the plans, specifications, drawings, etc., connected with the work to be done, are not in conformity to this ordinance, he shall thereupon forthwith give notice in writing to the person interested, setting forth specially the grounds of objection, and upon the said parties or persons complying with the order of said City Engineer, so soon as the plans and specifications shall be submitted, if the same be correct, to approve them in writing, and issue a permit, authorizing the construction of said house drainage.

PLATE II Plan of Plumbing and Drainage.



76. It shall be the duty of every person making or owning any drain, soil pipe, passage or connection between any sewer and any ground, building, erection or place of business, and in like manner the duty of the owner of all grounds, buildings and erections and of all parties interested therein or thereat, to cause and require that such drains, soil pipe, passage and connection shall at all times be adequate for its purpose and shall at all times allow freely to pass all that enters or should enter the same; and no change of the drainage, sewerage or the sewer connection of any house shall be permitted, unless notice thereof has been given to the City Engineer and assent thereto obtained in writing.

77. No drainage, sewerage or plumbing shall be covered or concealed in any way until after it has been examined and approved by the City Engineer or his accredited representative. Notice must be given to the City Engineer when the work is sufficiently advanced for such purpose, and it shall be the duty of said City Engineer, within three days after said notice, to inspect the same, and in case any change therein shall be found necessary, he shall direct in writing the change to be made. In no case shall any pipes, traps, or other plumbing work be permanently concealed in floors or partitions, but shall be left easy of access.

78. The main drainage of every house or building shall be separately and independently connected with the street sewer, where one is provided, and where there is no sewer in the street, and it is necessary to construct a private sewer to connect with one on an adjacent street, such plans must be used as may be approved by the City Engineer, but in no case shall a joint drain be laid in cellars, parallel with street or alley. All house drains or soil pipes laid beneath the cellar floor shall be of extra heavy cast iron pipes, with leaded and caulked joints, or of anti rust wrought iron pipe with screw joints. All other drains, soil or waste pipes, connected with the main drain, or where the main drain pipe is above the cellar floor, shall be of cast iron pipe, or of anti-rust wrought iron pipe with screw joints properly secured, and carried five feet outside of house walls, and all arrangements of soil or waste pipes shall be as direct as possible. All changes in direction on horizontal pipes shall be made with "Y" branches; all other changes shall be made with curved pipes, and where such pipes pass through foundation wall, a 2-inch clearance above and on each side of main pipe shall be provided for. All vent pipes in any building must be extended 2 feet above the roof of the main building, and above the top of any window in said roof. The diameter of any soil pipe should not be less than 4 inches.

79. All joints in iron drain pipes, soil and waste pipes, must be either screw joints tightly drawn up with red lead, or must be filled with

oakum and lead and hand-caulked so as to make them gas tight. All connections of lead with iron pipes must be made with brass sleeve or ferrules of the same size as the lead pipe, put in the hub of the branch of the iron pipe, and caulked with lead. The lead must be attached to the ferrule by a wiped or overcast joint. All connections of lead waste pipes shall be made by means of wiped joints.

80. In every water closet, urinal, sink, basin, wash tray, bath, and every tub or set of tubs, the waste pipe must be separately and effectively trapped and ventilated, unless the same shall be within 10 feet of the main soil pipe and an approved anti-syphon trap be used. Traps must be placed as near the fixtures as practicable, and in no case shall the waste from the bath tub or other fixtures be connected with a water closet trap. There shall be no traps, caps or cowls on soil or waste pipes which shall interfere with the system of ventilation.

81. All soil, waste, anti-syphoning pipes and traps, before being connected with fixtures, shall have openings stopped and be tested for inspection by filling them with water from the highest point, and allowing the water to stand in them until the inspection is completed and all leaks caulked, or by a monometer to ten pounds per square inch pressure, and all leaks stopped.

82. No pan or hopper closet shall be set up in any building. Every water closet or line of water closets, on the same floor, shall be supplied with water from a special water closet tank or cistern (the water of which is not used for any other purpose), except where the supply of water is assured, and no steam exhaust or steam from the waste pipes shall be connected with any house drain or soil pipe. No opening shall be allowed in the sewer pipe of any building for the purpose of receiving the surface drainage of the cellar, unless special permission is granted, and in accordance with the specifications of the City Engineer. No brick, sheet-metal, earthenware or chimney flue, shall be used as a sewer ventilator, or to ventilate any trap, drain, waste, or soil pipe.

83. The least inclination that can be allowed for water closet, kitchen and all other drains of not over 6 inches diameter, liable to receive solid substances, is one-half an inch in two feet; and for cellar or other drains, to receive water only, one-fourth of an inch in two feet. The depth of the crown of a drain at the curb line should be determined by a rise of one-fourth of an inch per foot from the crown of the sewer directly opposite.

84. The ends of all pipes not to be immediately connected with are to be securely stopped by brick and cement, or other water-tight and imperishable materials.

85. All pipes that must be left open to drain cellars, areas, yards or gardens must be connected with suitable catch-basins, the bottom of

which must not be less than two and one-half feet below the bottom of the outlet pipe, the size, form and construction of which are to be prescribed by the City Engineer. When meat-packing houses, slaughter-houses, lard-rendering establishments, hotels or eating-houses are connected with the sewers, the dimensions of the catch-basins, or grease-traps, which must be used, shall be required to be of size according to the circumstances of the case. When the end of the drain pipe is connected with a temporary wooden catch-basin for draining foundations during the erection of buildings, the drain layer will be held responsible for dirt and sand getting into the drain or sewer from such temporary catch-basin.

86. No private catch-basin can be built in the public street, but must be placed inside of the lot to be drained, except when the sidewalks are excavated and used as cellars.

87. The inside of every drain, after it is laid, must be left smooth and perfectly clean throughout its entire length; and to insure the same a scraper of suitable material, of the shape of the pipe and slightly less in diameter, shall be drawn through each length of the pipe after it has been laid.

88. The general plan of waste plumbing shall be in accordance with Plate II, Figures 1 or 2, as may be preferred.

89. The open ends of vent or air inlet pipes must be protected from stopping by a well-secured wire screen or perforated cap of sufficient size.

90. Drip or over-flow pipes from safes, under water closets and other fixtures, or from tanks or cisterns, shall be run to some place in open sight, and in no case shall any such pipe be connected directly with a drain pipe. No waste pipe from a refrigerator or other receptacle in which provisions are stored shall be connected with a drain or other waste pipe. Overflow pipes must in all cases be connected on the inlet side of the traps.

91. In case the general arrangement shown in Plate II, Figure 2, is followed, there must be a fresh air inlet pipe entering the drain on the house side of the running trap, of not less than four inches internal diameter, extending therefrom to the outer air, away from all windows and cold air duct of the furnace, and protected from dust or obstruction. The running traps must be so arranged that they can be readily cleaned and examined.

92. Every vent or anti-syphon pipe shall be of lead, or galvanized iron pipe with screw joints, or of cast iron pipe, tar coated, with caulked and leaded joints. These pipes, when not vertical, must always have a continuous slope, and be so arranged that water cannot collect in them.

93. Water closets must not be located in the sleeping apartment of

any building, nor in any room or apartment which has not direct communication with the external air, either by a window or air shaft having an area to the open air of at least four square feet.

PENALTY.

94. If any person shall violate this ordinance, or wilfully disobey any written order of the City Engineer as aforesaid, unless the same shall have been set aside or modified by judicial authority on appeal, or on the order or decree of the said judicial authority made on appeal as aforesaid, he shall be guilty of a misdemeanor and shall be punished therefor, and on conviction thereof shall be fined not more than one hundred dollars.

95. All ordinances or parts of ordinances in conflict herewith are hereby repealed.

96. This ordinance shall be in force from its passage.

PAVEMENTS OF CLEVELAND, OHIO, COMPARED WITH THOSE OF OTHER CITIES.

A REPORT SUBMITTED TO THE CLEVELAND CHAMBER OF
COMMERCE.

BY JAMES RITCHIE, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read January 8, 1895.*]

TO THE BOARD OF DIRECTORS OF THE CLEVELAND CHAMBER OF
COMMERCE—Gentlemen: I beg leave to submit to you and to the
chamber a few figures collected by me in my correspondence with several
of the large cities of the country relative to the cost and the methods
of construction of street pavements, comparing them with the conditions
which obtain in this city.

Reports have been received from Buffalo, Chicago, Milwaukee,
Indianapolis and Memphis, which are complete; from St. Louis and
Pittsburg, which are partial reports, while no answers have as yet been
received from New York, Philadelphia, Boston, Cincinnati, Detroit and
Louisville. By an examination of Poor's Manual for 1894 I have
obtained figures for the last three columns in table No. 3, and these are
undoubtedly correct.

Cleveland, with its mileage of streets of 544.71, has only 95.7, or
about 18 per cent., paved. The average expenditure for new pavements
during the ten years from 1884 to 1893, inclusive, was \$323,031 per
year, and in 1893 the expenditure was \$860,992.

Buffalo has a total mileage of streets of 702.73, of which 302.73
miles, or about 43 per cent., are paved. The average expenditure for
new pavements during the same period of ten years has been \$1,088,073
per year, more than three times our average, and the expenditure in
1893 was \$1,618,794, nearly twice what Cleveland expended. And yet
our tax per capita is only 5 cents less than that of Buffalo, if the figures
of Poor's Manual are correct.

The pavements of Cleveland consist largely of Medina stone, which
is laid directly upon the ground after the same has been flooded and
rolled, but in only one instance until this year has this city used a concrete
foundation for its block stone pavements. In Superior Street,
between the Public Square and Water Street, the new pavement was
laid upon a concrete base, and is referred to in the engineer's report for

* Copy received March 6, 1895.—*Secretary, Assn. Eng. Soc.*

1893 as "the only instance in the city, excepting in the case of asphalt pavements, where a concrete base is used." This shows that we are advancing slowly to the point reached years ago by other cities of less importance than we are in other particulars.

Our brick pavements consist of a single thickness laid on sand, and I have been unable to find an instance of this kind of pavement mentioned in the reports I have received from other cities, all being in the habit of using a concrete base, except when two layers of brick are used.

In all the reports there is a universal agreement that the pavement giving the best results is the block stone laid on concrete, although asphalt and brick are mentioned as preferable for residence streets.

The reports from Buffalo are the most complete of any I have received, and show a creditable spirit of enterprise, as well as an attention to detail, which could be advantageously followed by our city. In their reports I find a description of their methods of construction of their pavements as follows:

The ground is prepared by excavating to a proper depth and form, and placing thereon a bed of concrete 6 inches in thickness, made of 1 part cement, 2 parts sand and 5 parts of $2\frac{1}{2}$ inch broken stone. This is rolled with a 5-ton roller. Upon this is placed a layer of sand 2 inches thick and the block stone is laid upon the sand. The blocks are from 7 to 12 inches long, 3 to $4\frac{1}{2}$ inches wide and $6\frac{1}{2}$ to 7 inches thick, laid with $\frac{1}{2}$ inch joints, which are filled with pitch at 300 degrees, or with cement. The cost of this pavement complete, including excavation, curbing and concrete, is \$3.50 per square yard.

The Superior Street pavement in this city cost \$3.51 per square yard for the stone and foundation only, not including excavation and curbing.

The brick pavements of Buffalo cost \$2.75 per square yard, and are laid upon concrete, the same as the stone, and their asphalt pavements cost \$3 per square yard. Both these figures include excavation and curbing. The following table, No. 1, shows the number of miles of each kind of pavement in the cities heard from:

TABLE No. 1.

	Block stone on sand.	Block stone on concrete.
Cleveland	77.40	.25
Buffalo		1.20
Chicago		22.60
Milwaukee		12.00
Indianapolis . . . . .		. . .
Memphis	12.46	1.97
St. Louis . . . . .	.84	45.06

	Brick on sand.	Brick on concrete.
Cleveland	15.40	. .
Buffalo		3.33
Chicago		1.10
Milwaukee . . . . .		. .
Indianapolis		13.77
Memphis		2.71
St. Louis . . . . .		. .
	Asphalt on concrete.	Wood block. Macadam and Telford.
Cleveland	2.90	. .
Buffalo	177.00	. .
Chicago	20.10	648.40
Milwaukee	2.00	44.00
Indianapolis	20.82	2.44
Memphis . . . . .	. .	1.86
St. Louis	5.27	8.35

This table shows the mileage at the close of the year 1893, and does not include any work done since that time, as far as I could learn, excepting Buffalo, which is reported to September 1, 1894.

Table No 2 gives the cost per square yard of the different kinds of pavements in the several cities heard from.

TABLE No. 2.

		Block stone on sand.	Block stone concrete.	
Cleveland		\$2 70	\$3 51	
Buffalo . . . . .		. .	3 50
Chicago . . . . .		. .	3 00
Milwaukee . . . . .		. .	2 80
Indianapolis . . . . .		. .	. .
Memphis		1 92	4 34	
St. Louis . . . . .		. .	3 00
		Brick on sand.	Brick on concrete	
Cleveland		\$0 90	. .	
Buffalo . . . . .		. .	\$2 75
Chicago . . . . .		. .	2 10
Milwaukee . . . . .		. .	. .
Indianapolis . . . . .		. .	1 85
Memphis . . . . .		. .	2 85
St. Louis . . . . .		. .	. .
		Asphalt on concrete.	Wood block.	Macadam.
Cleveland		\$2 85
Buffalo		3 00
Chicago		2 85	\$0 95	\$0 80
Milwaukee		2 28	1 05	. .
Indianapolis		1 55
Memphis	1 92	1 15
St. Louis		2 75	2 75	0 75

I have also prepared a table showing the comparison between total mileage of streets and mileage of paved streets, expenditures for paving and the tax rates and bonded debt of each of the cities heard from, as follows: (Poor's Manual.)

TABLE NO. 3.

	Population 1890.	Miles of Streets.	Miles Paved.
Cleveland...	261,353	544 71	95.71
Buffalo	255,664	702.73	302.73
Chicago	1,099,850	2,467.00	1,003.00
Milwaukee	204,468	261.00	58.00
Indianapolis	105,436	299.60	41.00
Memphis.	64,586	88.00	39.32
St. Louis.	451,170	767.95	359.45
Pittsburg	238,617	220.00	175.00
	Expenditures 1893.	Annual Average.	
Cleveland	\$860,992	\$323,031 (10 years)	
Buffalo.	1,618,794	1,088,078 (10 years)	
Chicago	3,596,536	3,026,779 (5 years)	
Milwaukee	154,000	158,900 (10 years)	
Indianapolis	765,043	555,960 (3 years)	
Memphis	63,688	92,000 (10 years)	
Pittsburg	763,301	
	Tax Rate per \$1000	Total Tax per Capita.	Bonded Debt, 1893.
Cleveland...	\$27.50	13.40	\$7,200,128
Buffalo.	15.45	13.45	12 975,829
Chicago.	46.08	10.30	18,097,221
Milwaukee	21.00	13.96	5,269,000
Indianapolis	17.60	15.00	1,899,500
Memphis	17.50	10.75	3,130,000
St. Louis	13.80	11.25	21,376,021
Pittsburg	13.00	15.00	8,483,995

The total tax per capita is obtained by multiplying the tax rate by the valuation for taxes, as given by Poor's Manual, and dividing the result, thus obtained, by the population.

The report of the city director of accounts shows the following:

January 1, 1894:

Amount of General Bonded Debt	\$6,129,000 00
Street Damage	\$70,000 00
Street Improvements	805,000 00
Sewer Districts.	619,000 00
Water Works.	1,775,000 00
	<hr/>
	3,269,000 00
Total Bonded Indebtedness.	\$9,398,000 00
Temporary Loans for Special Improvements	220,823 00
	<hr/>
	\$9,618,823 00

Temporary Loans Account Brooklyn village	\$7,044 92
Total City Debt	\$9,625,867 92
Sinking Funds—General	\$1,167,289 60
Viaduct	982,204 99
Total	\$2,149,494 59
City debt less sinking funds	\$7,776,373 33
The total receipts from all sources in 1893, including cash on hand Jan. 1, were	\$7,215,448 66
The total disbursements were	5,200,355 25
Leaving a balance on hand, Jan. 1, 1894, of	\$2,015,093 41
The tax levy for general expense is \$13.20 per \$1,000, and amounts to \$1,726,943.25, and of this there was received in 1893.	\$1,621,967 62
Of sewer tax	120,362 52
Of special tax	550,935 45
Of liquor tax	386,440 09
Portion of 1894 taxes	200,000 00
From sale of bonds.	1,779,519 10
From sale of notes	177,888 00
From gas companies	42,113 00
From removal of night soil	31,502 72
From Cleveland City Railway (paving)	2,493 40
From sale of city farm	1,750 26
From special improvements and miscellaneous funds paid in	60,813 81
Earnings credited to different funds	931,100 94
Total receipts	\$5,906,886 01
Cash on hand, Jan. 1, 1893	1,308,562 65
	\$7,215,448 66

Of this money there was paid out in 1893, for street pavements, the sum of \$860,992, which is about 17 per cent. of the total expenditure of \$5,200,355 previously noted.

The ordinary expenses of the city government for 1893 were \$1,798,556.29, which is divided as follows :

Current expenses, Mayor	\$38,568 63
“ “ Public Works	146,597 37
“ “ Auditor	20,843 68
“ “ Law	13,873 24
“ “ Charities and Correction	1,253 92
“ “ Legislative	34,658 32
“ “ Treasurer	8,574 92
“ “ Elections	14,458 52
“ “ Judicial	31,761 45
Total general fund	\$310,590 05

Carried over	\$310,590 05
Bridge fund	86,609 82
Street fund	139,033 56
Water Works	185,082 70
Parks	30,850 04
Police	325,771 16
Police court	23,676 94
Markets	24,188 76
Sanitary	35,950 99
Cemetery	26,344 12
House of Correction	111,163 07
Infirmary	128,133 58
Fire department	346,403 38
Dredging fund	24,758 12
	<hr/>
	\$1,798,556 29

These figures and others in the auditor's report show that the ordinary expenses of the city government are about 35 per cent. of the total expenditures. This does not include new and permanent improvements, but is supposed to include salaries, office expenses and the general expenses incident to maintenance and ordinary repairs.

The special improvements and the permanent improvements in 1893 cost \$1,737,784.35, or about \$60,000 less than the charge for maintenance and general expenses. The interest paid on bonds and notes was about \$954,000.

These figures show, in relation to the subject in hand, that while our city has expended over \$5,000,000 in 1893, only about one-third has been expended for permanent improvements and about one-half of that amount has been for new pavements. And, while these are called permanent improvements, only one section of the stone pavement and none of the brick pavements laid have been done in what is usually considered a permanent manner. While it is undoubtedly true that our pavements compare favorably in some respects with pavements of other cities, I think great improvements could be made in the methods used in the work of construction. There is not enough attention paid to obtaining the best results. Permanence in construction means economy in repairs, and every means should be taken to secure good foundations and proper materials. The appointment of inspectors should be regulated by the ability of the men and their knowledge of the character of the work and methods to be used, and political influence should be utterly disregarded. The federal plan of government enables the officials to disregard the matter of politics when they desire to do so, and our citizens should see that the officials are men who will throw aside personal and political feelings and only work for the general good.

The methods employed in the maintenance of our streets are being

improved. Efforts are being made to change the character of our street department from its condition of a "rest for the infirm," as the report of the department of public works states, and the result has been to place it upon a business-like basis. Certain reforms have been made and more will come. Our streets, however, are at no time clean, and the mud upon our pavements should be kept down. Yet the principal reason for their being in such a condition is the fact that from all sides there are dirt roads entering the city, intersecting our paved streets and depositing, through the medium of hoofs and wheels, their mud and dirt upon our pavements. Also, as shown in the tables within, we have only 18 per cent. of our streets paved, and the other 82 per cent. are assisting in the defilement of our pavements. In 1893 the street department expended over \$138,000 in material and labor for repairs to street pavements, sewers, drains, catch-basins, and cleaning the streets, sewers, and catch-basins. The item for cleaning paved streets amounts to about \$30,000 for 1893, which is about \$300 per mile for the year. The cleaning, rounding and filling of unpaved streets costs the city over \$52,000, and this appears to be a waste of money. After the first heavy storm the surface of these streets was deposited upon the adjoining pavements. Three hundred dollars per mile per year for cleaning the paved streets does not seem like a waste of money, but when a street becomes immediately in the same or worse condition, we feel impressed by the uselessness of the work. There is a remedy which our city must apply, and that is to proceed at once to make such permanent improvements in the way of draining and paving that before long our whole city will be in such a condition that dirt upon our pavements will be unknown. Let us see what such a move involves. Until a street is to be paved the old sewers are usually considered sufficient; consequently, when new pavements are put in, a new sewer has usually to be built. Last year (1893) there were built 13.986 miles of sewers of various kinds, at a total cost of \$317,272.40, or an average cost per mile of about \$22,700. There were paved 18.67 miles of streets, at an average cost of about \$46,600. The average cost, therefore, of draining and paving the streets of this city is \$69,300, or say \$70,000 per mile. There are about 400 miles of unpaved streets, which, if paved and improved, would give this city an advantage over many others in appearance and in healthfulness.

Four hundred miles at \$70,000 per mile would be \$28,000,000. If we should keep up our present rate we should accomplish this result in about twenty-five years, if it were not for the fact that a part of our work each year is repaving. There is where we lose money by our economy in first cost and our old-fashioned methods. It costs Buffalo 80 cents more per square yard for stone pavement laid on concrete, than it costs us for stone pavement on sand; that is 30 per cent. There

can be no doubt in the mind of any one as to the superior advantage of a pavement with a foundation over one without. These advantages are as follows :

The concrete is calculated to so distribute the loads and weights of the pavement as to prevent unequal settlement, and is practically the same thing as a single band of solid rock upon which to support the surface. The two inches of sand act as a leveler and cushion, preventing the inequalities in the upper surface of the concrete from being felt in laying the stone, and preventing the blows from heavy traffic of the street from being too suddenly communicated to the concrete. The pitch, which fills the joints, prevents water from penetrating to the foundation, where it would freeze and heave the stone irregularly and at the same time damage the foundation. With this kind of pavement it is essential that the engineer shall have sufficient foresight to enable him to put in absolutely all the pipes and curb connections needed, for it is practically impossible to replace a pavement of this sort and make it as good as at first. The wearing surface of this pavement will last better than our present ones, will retain its form and evenness, and, when it requires changing, can be taken up without disturbing the concrete, and new pavement can be laid at a less expense than it costs us to repave. Adding to our estimate of \$28,000,000 the extra cost for concrete foundations, we have about \$35,000,000 as the estimated cost of these improvements. Our valuation for taxes is about \$126,000,000, and the expenditure of \$35,000,000, which is over one-fourth of our valuation, looks like a preposterous idea. But what would the result be? Experience in other cities has shown that the value of the abutting property is increased to a great extent by such improvements, and I have no hesitation in saying that an expenditure of \$35,000,000 in our streets and sewers would so increase our valuation that the advantage to our city would be enormous.

In cities with good pavements the rates of fire insurance are less than in those having inferior streets. Again, we would gain from pavements.

Cleanliness is next to godliness, and, as we can never hope for the latter in a large city, let us secure the former and conduce to the public health by keeping our streets clean and our sewers in order.

Speaking of sewers, I hope the time will come before long when the Cuyahoga River shall be cleaned and purified. There are ways to do this, and among other means I would suggest that instead of emptying our sewers into the river, we construct an intercepting sewer on each side of the river into which all sewers must empty, and, connecting these two into a main sewer along the lake front, let the latter empty into the lake as far east as possible. This is merely a suggestion, and

the details of it, when worked out, might show obstacles and objections not easy to overcome except at great expense and by the use of machinery and pumps. But it seems to me that unless something is done very soon the health of our people, and thereby their usefulness, will be destroyed and our city will become a nuisance to itself and to the world.

What we need is a spirit of push, energy and ambition, together with the pride in ourselves and our city which conduces to growth and improvement. There has been too much holding back and objecting when public improvements are proposed; too many citizens who do not see that the interest of the whole city is their interest, and the improvement of a part of the city indirectly helps the whole.

DISCUSSION.

MR. M. E. RAWSON.—For a great many years I have been connected with work on the city pavements, and I have yet to learn just how to pave and with what material. Our pavements compare favorably with those of other cities. I think there are some pavements down to-day that were laid in 1858, 1859 and 1860. They are therefore 35 years old. What more could six inches of concrete foundation have done? If we had foundations of clay or drift as they have in Chicago, we should have done differently from what we have done. Perhaps we have made a mistake in not putting in foundations earlier; but it does not follow that because they do it in Chicago or in Buffalo that, therefore, it should be done in Cleveland; for we have very different soil. We are continually digging trenches 6, 10 or 20 feet deep. If these give way neither six nor twelve inches of concrete will hold the pavement after the foundation has given way under it. Trenches are liable to go down, and will go down in spite of all the care you can take. I believe the time is coming when we should put down more concrete foundations of broken stone as the traffic of the city increases. We must provide artificial drainage and carry the water away from the foundations. All of our block stone, and, in recent years, all of our common stone pavements, are laid with cement filling which is impervious to water, and the surface water is thus shut off. In some places, where they are putting in concrete foundations, they are simply filling in the pavement with sand, which allows the surface water to reach the foundations.

Mr. Ritchie has said that before the engineer commences to pave a street, he should have such a knowledge of it that he can put in every pipe and every connection which will be needed in the future. No man

has ever been found that can do that. You cannot tell where six-inch or four-inch water connection, or six or nine-inch sewer connection will be wanted. These things cannot all be anticipated. The gas companies and water works are continually enlarging their pipes. A sewer built years ago and sufficient for that time, is found inadequate when larger blocks with deeper basements are built. The house which a man builds when he is worth four thousand dollars is different from that which he builds when he is worth ten thousand, and different again from the one he builds when he is worth fifty thousand. It is so with towns of ten, fifty and one hundred thousand inhabitants.

In Buffalo, nine-tenths of all the pavements are asphalt; they are beautiful to look at, and, when made as well as they can be made, are very satisfactory; but I have seen some pavements there with concrete foundations that do not compare with our pavement on Superior Street, laid only on earth foundations. It does not follow that because Case Block was built upon a pile foundation, that therefore the City Hall on the opposite corner should have had that kind of a foundation. When they built the City Hall, the ground water had been drained nine or ten feet deep and the conditions were entirely changed. And so a concrete foundation for a pavement is not better if it does not serve a better purpose. It does not follow that six inches of concrete would be better because it costs more. A city engineer cannot always do the thing that he would. Every man here is a king, he owns his property and a right to the street in front of him, and he has his say. The City Council is made up of individuals who are susceptible to his influence, and no engineer can crowd his own ideas through the Board of Control or City Council. I believe we ought to have better pavements, and I think we should get into our specifications something that will make them better. I believe Medina stone is the best material we have in this section for streets of heavy traffic. Pavements of this material do not become brittle or slippery. They do not make as smooth a pavement as brick, or as easy a pavement as asphalt. Asphalt, when it is as good as it can be made, makes a beautiful pavement; but laying an asphalt pavement is a good deal like making bread. It may be successful to-day, and to-morrow it may not be so successful. The failure may not be the fault of the contractor. In one street where a portion of the pavement was taken up after it had been down but a short time, the contractor told me that he thought the material first class, but that it must have been chilled in transit, as it was late in the Fall when laid. You cannot always select your contractor, where the cheapest contractors get the work. I wish someone would tell us a better way.

MR. JOHN L. CULLEY.—I quite agree with Mr. Rawson in what he has

to say relative to the use of concrete base under sheet pavements. Concrete base for pavements has become a fad with engineers all over the country, *per se*. It must be used without regard to local requirements. In many of our smaller cities this has been a fruitful source of municipal extravagance and of burdensome taxation. As a general rule it may be stated that for corporations of less than 10,000 inhabitants there is no traffic to warrant the use of concrete base under pavements. In determining the question whether such base is a necessity, the character of the soil and of the traffic should be the directrices. Throughout the resident portion of Cleveland there is no necessity for concrete base over our sandy, gravelly soils, nor is there over clay soils or for drift if the sub-grade is properly drained and prepared. Some four or five years since I had charge of the brick paving of the west end of Detroit Street, then in the corporation of West Cleveland, on the worst kind of soils, composed of clay, drift and "wash stones." The sub-grade was excavated to crown 12 inches between the bottom of the pavers when in place. These 12 inches were then filled with a gravel of good quality, thoroughly puddled and rolled. Ordinary 4-inch field tile were placed under each curb. This pavement does not to-day show any signs of wear or of settlement. Undoubtedly, such a pavement, in business localities of concentrated traffic, would not be able to stand up, and would need a stronger base.

Engineers, accustomed to concrete or other hard base under pavement for residence streets, are surprised to find us using earth under ours. They are also surprised to see them stand up here. The reason for this lies in the better preparation of the base, and in the superior construction.

A weak point in pavement construction in this city is the method of refilling with earth and water, sewer and gas pipe trenches, particularly the sewer trenches. They are refilled by (so-called) puddling in the earth.

Specifications require each 18-inch layer of earth to be flushed or puddled with water. Practically the trenches are filled up at once within 18 inches of grade before any puddling is done. Naturally, water turned into a trench thus prepared quickly finds its way to the sewer. The earth is not compacted, and a depression is soon developed in the pavement over the sewer. All of this may be avoided by tamping in the whole trench from sewer to street grade. One rammer to two shovels will answer. This involves no increase of cost over puddling. The expense of carting away the surplus earth in sewer construction would more than offset that of ramming it back into the trench. All this work, of course, should be done under the sewer contract.

COL. J. A. SMITH.—Of course, everyone knows that one of the greatest dangers to our pavements is due to the settlement that comes from the earth becoming more compacted in these trenches that have

been dug. I have noticed that in almost all cases they return the earth by the process of puddling; sometimes by the trenches being filled, and sometimes by poling it in when the trenches are nearly full. There seems to be an idea that by getting water into the earth they get more of the earth back than otherwise. That may be true with certain limitations of labor saving. There may be more earth settled back when we puddle it in than when it is simply shoveled without ramming. I think this idea was derived from the fact that when we puddle a dam it is less likely to be permeated by the water. But the principles involved in the two cases are different. Many years ago my old friend, W. J. McAlpine, the former president of the American Society of Civil Engineers, in conversing with me, dropped this remark: "Water abhors a vacuum;" and in the subsequent discussion this remark was considerably elaborated. A particle of water, passing through a puddled dam, finds no cracks or seams, but must turn constantly at every moment of its passage, so that ultimately the friction and the other resistances it meets tire it out and stop the leakage. That same principle is found in a thousand things we meet in hydraulic engineering. But it does not follow that the quantity of material in a dam is what causes its imperviousness. Because the dam does not leak when it is puddled, it does not follow that there is more material in it, but merely that the material is so disseminated that the water cannot find passage. If the earth were replaced in thin layers and thoroughly rammed, I think the subsequent trouble would be reduced to a minimum. I do not know whether it could be prevented entirely. I believe the use of water, instead of being a benefit, is a positive injury.

MR. H. M. CLAFLEN.—It is now thirty years since I commenced to do paving, and during that time I have laid, in eighteen of the larger towns, from Rochester to Chicago, every kind of pavement I know anything about. No man has ever yet laid a perfect pavement. The Appian Way comes as near to it as anything, but the construction there used is among the lost arts. The subject of pavements is of more importance to a city and to the people of this country than they appreciate. A well-paved town and clean streets bespeak the character of the population of that town. I do not think the engineers are always responsible for poor pavements, any more than architects are always responsible for poor buildings. Suppose an architect is requested to make plans for a block. He submits them with estimate, and the proprietor says "No, can't stand it; cut that in two." What is the result? You see it all over Cleveland, and you cannot blame the architect. It is so with engineers. If you had assessed upon property owners fifteen years ago a tax that would permit the laying of a first-class pavement, I have no doubt there would have been a "kick." This

city has been slow to progress in that matter. Sixteen years ago I laid the first block pavement that was laid here, and I could not get any pay for it at all. I am not paid for it to-day. Why? They thought I was crazy to lay such a nice piece of pavement, and they would not pay for it even as the price of a common pavement. It is in existence to-day, and people saw in due time the result and began to want that kind of pavement, and I have laid many miles here, as well as in other cities. As a general principal of engineering, the man who puts in scant material, and the man who puts in more than is necessary, are both guilty of poor engineering.

In reference to foundations of pavements, the success of the block-stone pavement which I was the first to lay in this country, and which was laid on a sand foundation, filling the interstices with cement which keeps out the water and preserves the foundation, has been to my mind a matter of wonder. There are pavements of this kind which I laid fifteen years ago, and which are in perfect condition to-day without any settling. But, if it were left to me, I think I should put a foundation under all pavements, both brick and stone; but I would not use concrete. I do not think it is necessary. In 1872, High Street, in Columbus, was paved with asphalt. Some ten years later the asphalt was taken out and the street was repaved with block stone. In doing that work we had the old concrete under the asphalt to dispose of in some way. It was picked up, leveled off and rolled with a heavy steam roller. On top of that was put a cushion-coat of sand, and in that was set the block stone, the interstices being filled with cement, and it is there to-day in perfect shape. Third Street was, soon afterward, paved with block stone, and the same specifications were adopted, and the street was paved in the same way. It is a perfect street to-day. Nearly all the paved streets in Columbus have been treated in the same way. The advantages of that treatment are, (*a*) saving in cost; (*b*) a street can be paved with less inconvenience without discommoding the business of the street.

Summit Street, in Toledo, is another instance of paving on a sand foundation. I paved that street with block stone about twelve years ago. Summit Street is on a bed of clay, and when it was paved a water-pipe was put in on one side, and a sewer on the other side, the railroad tracks were relaid, and water and gas connections were put in. It looked as though the rabbits had occupied it. However, we replaced this material, ramming it thoroughly. Puddling was impracticable. We put on twelve inches of good lake sand, and paved the street in that, and it is as pretty a piece of pavement as there is in that or any other town. It has not settled. But my suggested broken stone foundation makes a sure thing in any doubtful case, and is not very expensive.

THE CHAIR.—During my recent trip abroad I often heard Ameri-

cans speak of the good pavements of London and Paris, and of the poor pavements in our large American cities. I believe our engineers understand the methods of laying pavements as well as those abroad, but in Europe they take a great deal more pains in putting them down and better care of them after they are down. In Berlin I saw them laying stone pavements of granite blocks perhaps an inch larger each way than those used by us. They first prepared the roadway with a heavy roller, and then put on the small broken stones. The stones were not tumbled in by the cart-load and then leveled off, but men on their hands and knees were carefully placing each piece in its proper place. They then put two or three inches of gravel on top, over which the block stones were laid. On the end of every stone was a large figure showing that it had been inspected as to quality, size and shape. They all seemed to be perfect stones, but there must have been considerable difference in them, for they were figured from one to four. The gravel for filling the spaces between the blocks was not dumped on top and washed in with a hose, as we have often seen it done here, but carefully tamped in. After the proper amount of gravel was put in, the remaining spaces were filled with cement. The work throughout seemed to be done with the greatest care, so that if there was to be any settling at all it should take place uniformly over the whole street, and not in spots. In London I saw a pavement being put down consisting of concrete about six inches deep, covered with a cushion of gravel upon which the granite blocks were laid.

Wood-block pavements, laid upon concrete, are extensively used throughout London and upon many of the streets having the heaviest traffic. Asphalt also is largely used, the same as in Paris. In these cities special care is taken to keep the streets in good repair. On the Strand I noticed they were taking up a pavement of wood blocks that had become somewhat worn and irregular, but which we would call in fair condition, and would probably have left it for several years. The wood blocks are quickly replaced by new ones, much of the work being done in the night. The splendid condition of the streets, together with the rubber tires, which are now universally used upon the wheels of the cabs, make driving about London very pleasant.

MR. CLAFLEN.—Of course, London is ahead of us about a thousand years in experience, but we have made great progress in this country, and with cheap money now attainable we can make further progress. When I laid the first pavement here on Superior Street, in 1868, I had to take 8 per cent. bonds in payment. I could not sell them here. I went to Boston and there sold, for 72½ cents on the dollar, the first chartered city bonds ever issued for paving. You can figure from that and see what it cost the people of this town to furnish money for paving at

that time, and how hard it was to introduce a first-class permanent pavement, which must be expensive at the first.

MR. A. H. PORTER.—I wish to say just a word in approval of the course that has been pursued by our engineers in the matter of paving here in Cleveland, up to the present time. We have read and heard so much about our poor pavements, that without a little reflection on our part, we are likely to think that a large portion of the money invested in our pavements has been actually squandered, while the facts are that the money has, in the main, been exceedingly well and judiciously expended, and we have to-day pavements that will compare favorably with those of any other city, of equal size, in the country.

I believe in doing all work, public and private, in the best manner possible, for the purpose in view; but to do this often requires the most careful study of the problem to be solved. It requires no more talent or skill to design a work which is too good and expensive, than it does to design one that is inferior and inadequate to the purpose for which it was constructed. Engineers have committed the first mistake far oftener than they have the second, and all of our cities and the country are full of works of this kind, but they are less known than the comparatively few failures that have been recorded and widely published. Extravagance has been far more productive of bankruptcy than a too sparing use of proper materials.

Cleveland is now paving large areas every year, and I am pleased to state that all that is laid under the specifications and supervision of our city engineer, is admirably adapted to the purpose for which it is to be used. The worst specimens that we have, those which have called forth a large part of the unfavorable comments we have heard, are those which have not been thus put down under the supervision of the city. There is no doubt that the most substantial pavement will last longest under the most severe traffic; neither is there any doubt that a cheaper pavement would last just as long on some other street with light traffic.

Cleveland is certainly well favored in one respect, and that is that the foundation of our pavements is the sand which underlies all of our streets, and which is easily drained as soon as a sewer is built. This can be wet and rolled so solidly that in walking across it not a footprint will be seen. It furnishes an excellent foundation for a cheap pavement on many of our side streets where traffic is, and probably always will be, light. I live on a street that has been paved with brick for three and a half years, and not a brick has been removed for any cause whatever, and there is not a broken brick on the street, nor a place that shows the slightest signs of settlement, even after a rain. This pavement was laid under the most rigid inspection, directly upon the sand of the street,

after it had been properly graded and rolled, and I believe that a better, cheaper and more satisfactory pavement is not to be had. I do not pretend that this would be suitable for all streets, but there are large numbers of streets in all of our cities where it would prove the ideal pavement. It can be laid and paid for in innumerable instances where some of the other kinds would almost cause practical confiscation of the poor man's property on the street. I also think that traffic should be so regulated by law as not to allow the destruction of our lighter pavements by a small amount of exceedingly heavy hauling, which can just as well take some other route where it will cause no damage.

PRESIDENT SWASEY.—Reference having been made to the Appian Way, I would like to say a few words in regard to that "Queen of Roads," which I visited a few months ago. One of the most interesting sights to the traveler in Rome is the ride of six or seven miles over that highway, built 300 years B. C. The road is composed of smooth flat stones about 2 feet across, of irregular shape, well fitted together. I measured the width of the roadway at several points about a mile apart, and found it to be 13 feet 9 inches from curb to curb, with scarcely any variation. For much of the way the original stones are left bare, showing their smooth, polished surfaces which almost glisten in the sunlight. These stones are so hard that they show but little wear from the wheels which have been passing over them for so many hundred years. The road extends as far as the eye can reach over the Roman Campagna toward Naples until it vanishes into a faint line over the mountains, and it is as true and straight as the engineer of to-day could lay it out with his most improved instruments.

As to the construction of the Appian Way being a lost art, we should consider where it is located and the conditions under which it was built. In the first place, the climate is all that could be desired. There is scarcely any frost or snow, and the atmosphere seems to preserve the building materials instead of destroying them. Structures which have stood in Rome for 2000 years, and will, no doubt, stand as long again, would, if in this country, commence to decay in a very few years. The natural foundation upon which the road is built could not be better, for it is the same volcanic tufa which was used in the Roman cement, and in which the Catacombs, beside the Appian Way, are excavated. These underground galleries, some of them with vertical sides 8 feet or 10 feet high, have stood, without caving in, ever since the second century; and no wonder that in such a climate and with such a foundation the hard flat stones of the Appian Way have remained just as they were laid 2000 years ago. I believe that if our Engineers were given similar conditions and materials, they could construct a road equally good.

CARBON DIOXIDE FOR REFRIGERATION AND FOR EXTINGUISHING FIRES.

EXTRACTS FROM A PAPER BY E. F. OSBORNE, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read November 7, 1894.*]

ATTEMPTS have been made to distribute artificial refrigeration in a limited territory by the use of anhydrous ammonia. The cost of this material necessitates its return to the central station, involving, in the construction of a plant, not only the pipe for its distribution, but pipes and fittings larger and several times more expensive than the distributing pipes, for its return; and in practice it has been found necessary to employ three pipes, with the attendant complication and expense, both in construction and maintenance. The meter measurement to the consumer is not satisfactorily operative, and automatic regulation is impracticable, if not impossible; still, the demand is so great for even this crude service, and it is so much superior to the use of ice, that consumers cheerfully pay a price sufficient to make a small and expensive plant of this kind commercially remunerative. Furnishing a product without measurement is commercially possible only on a limited scale.

I do not wish to detract one iota from the credit that is due to those who have perfected the ammonia refrigerating machine, but the causes that have almost invariably effected a failure in district steam heating plants operate to produce a failure in district refrigeration by the ammonia process, to wit: Too great complication and expensive construction, no practical system of meterage or means of regulating the effect produced, together with excessive expense for maintenance and inspection.

Pipe-line refrigeration has come to stay, and will displace ice for nearly all purposes for which the same is now used; and some system other than that in which ammonia is used must and will be used in all places where refrigerating effects are to be produced on a large scale, and divided among many small consumers, in the same way that natural and fuel gas has replaced steam for heating purposes under similar conditions. Carbon dioxide is the substance to be employed for the following reasons, namely:

Less cost of production, less complication and therefore less expensive construction; less cost of maintenance and less need of inspection,

* Manuscript received March 18, 1895.—*Secretary, Assn. Eng. Soc.*

together with accurate measurement of product and easy regulation of effect, with incidental uses not obtainable with ammonia.

The following may be called a commercial law :

No commercial enterprise on an extensive scale can attain and maintain enduring success that must recover its product; that has no substantially accurate and readily comprehended means of measurement upon which to base charges for product furnished, or that cannot regulate, either automatically or readily by the assistance of the consumer, the effect produced by the product furnished.

Carbon dioxide possesses the physical properties and can be produced, delivered and furnished to small consumers under such conditions as to force its adoption for the many purposes for which it is so pre-eminently adapted. It can be produced so cheaply that its recovery would materially increase the cost of its production. It is comparatively a harmless gas, as it is a necessary constituent of many articles of food and drink. It is the best available refrigerant known to science, being capable of producing a temperature in a few minutes even more than 100 degrees below zero Fahr. It is, therefore, useful in many chemical processes where ammonia could not be employed. It is odorless, and neither inflammable, corrosive nor explosive. It is the best preservative of furs and woolen goods known, keeping them from the ravages of insects and worms without impregnating them with any odor.

The loss occasioned by the average fire is due more to the water than to the fire. In many cases the amount of goods actually consumed or damaged by the fire and smoke is less than one-tenth of the damage done by the water used to extinguish the fire.

The well-known properties of carbon dioxide to extinguish fires have been used in portable fire extinguishers and chemical engines. One of the advantages of carbon dioxide for extinguishing fires is, that the heat produced by the fire assists in its own extinction by inducing a current of mixed air and carbon dioxide to flow to the point of combustion, and thereby extinguishing or wiping out the fire just as water would be wiped off from either a vertical or horizontal surface with a dry sponge or rag drawn over it.

I have devised a system and devices by which carbon dioxide may be produced in a liquid form on a large scale, at a comparatively insignificant cost; and have devised processes, methods and apparatus for its utilization. The devices are simple in construction, readily understood by the average mechanic; they are easily constructed and put in operation and can be tested at any time without danger to the operator.

It requires but a very small amount of gaseous dioxide to extinguish a fire in its incipient stages, from 4 to 10 per cent. is ample. As the gas comes out it falls to the floor, mixing with the air as it goes. The heat

caused by the fire induces a flow of the mixed air and gas to the exact place where the combustion is going on, and immediately extinguishes it. As soon as the fire is extinguished, the temperature of the air at the ceiling is reduced, the thermostat ceases to operate, the automatic valve closes, and the apartment is in the same condition as it was before the fire.

This gas can be adapted for use in refrigerator cars. It will also give preservation with a dry atmosphere, with but little refrigerative effect, or a freezing temperature to keep frozen goods.

The system consists of a central station provided with one or more gas producers, calcining retorts, distilling apparatus, boilers, engines, pumps, compressors and incidental apparatus. The raw materials required are soft coal and limestone. The products are carbon dioxide, commercial lime, carbonate of ammonia and coal tar.

The coal is supplied to retorts, and subjected to destructive distillation, in nearly the same manner as in ordinary gas works, the tar and ammoniacal liquor being separated, the former being sold in that state and the latter distilled and converted into carbonate of ammonia, packed and sold. The coke is converted into a semi-water gas, which is used to calcine the limestone. The lime produced is of the best quality and is sold on the open market either in bulk or by the barrel. The dioxide is purified, cooled, compressed and liquefied in the same way as is done in ordinary manufacturies where this substance is produced for commercial purposes. The liquid dioxide then passes by its own pressure into the main distributing pipes in the street. At the curbstone is a service cock; just inside of the consumer's premises is an automatic valve, which cuts off the supply in case of a break or careless management of the apparatus on the consumer's premises; if the break is permanent, or anything has happened equal to a rupture of the service pipe, the supply remains substantially shut off. When the damage is repaired and normal conditions established the supply is automatically turned on. From this valve the dioxide passes to a meter, thence to the automatic regulating valve in the refrigerator, which is set to maintain any temperature desired, from which valve the dioxide is conducted into the cooling chamber or coil located in the space to be cooled. Thereafter the dioxide in gaseous form may be used to charge drinking water, ale, beer or wine, and for forcing these or other liquids from a lower to a higher level, as from the basement of stores and restaurants to any floor above; or the gas can be used for the preservation of nearly all kinds of food products, where a low temperature is not necessary, especially for fruits, vegetables and meats. It can also be used for small powers, and the heat that is extracted from the substances cooled goes a long way towards furnishing the motive power required in connection therewith.

Briefly, the services above referred to are to be furnished from a central station, somewhat similar to a gas or water works plant, and the carbon dioxide, after its production, delivered into flasks or cylinders for use on board cars, ships, or at other places not directly connected with the central station. Or, the dioxide is delivered into a ramification of pipes leading to the premises of the various consumers where it is metered, automatically regulated, and the resulting gas allowed to go to waste.

One ton of good soft coal and $3\frac{1}{2}$ tons of limestone will produce rather more than 3,500 pounds of lime, 3,000 pounds of carbon dioxide, 6 to 7 gallons of coal tar and 40 to 50 pounds of carbonate of ammonia.

RAILROAD SIGNALING.

BY CHARLES S. CHURCHILL, MEMBER OF THE ASSOCIATION OF ENGINEERS OF VIRGINIA.

[Read January 17, 1894.*]

IN the most primitive method of operating a railroad all trains are scheduled and have stated meeting points. Each meeting point must be made within a given time limit. This plan primarily requires no signals; in other words, the absence of a danger signal means safety. Carrying out this general idea, switch stands are sometimes made with but one target; the edge of that target faces the train when the main line is clear, and the whole target shows at danger when the main track is not clear.

As the business on a road increases, this primitive method requires extension and change. At given points along the road, at distances as nearly uniform as possible, telegraph operators are stationed, who, acting under a dispatcher, give special train orders, using a danger flag or its equivalent when orders are at hand.

In the next advanced step, all train-order stations are equipped with fixed signals, each conveying one of the three ideas—danger, caution and safety—and controlled by the operator under the direction of a train dispatcher. The absence of a signal still means safety, and a fixed time interval is required between all trains. French roads are mostly operated on this plan, and it is said that, notwithstanding its defects, good results are secured, the system being carefully worked out. Many miles of railroad in this country are still operated on this plan.

Under the next more advanced plan the movements of trains are governed by telegraphic orders in addition to time tables. This requires a number of offices along the line of the road, with an operator on duty in each, and a fixed signal under the control of the operator, directed by the train dispatcher. Each signal shall show danger except when changed to safety to allow a train to pass, after getting orders, or after ascertaining that there are no orders. In this system the absence of a signal means danger, and requires a stop, with the protection of the trains under the rules. The time interval is in force, since there are often more than one train between two train-order offices at the same time. Very many miles of road in this country are operated under this system. The distance apart of the train-order offices is determined by the amount of traffic to be handled.

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A still further improvement, both in safety and in rapidity of train movements, is secured by dividing the road into blocks; *i. e.*, approximately regular spaces, and placing at each end of each block an operator controlling the signals under the direction of the train dispatcher. In this case the operator may show three forms of signals: first, a signal signifying safety and giving the information that the track is clear, subject to the regular schedule; second, a cautionary signal, showing that a train has preceded at a given number of minutes constituting the time interval; or, third, a danger signal, showing that the track is occupied or requiring a train to stop for orders. This system, in its most complete form, is known as the "Block System," and, in its most complete manner of operation, is known as the "Absolute Block." The time interval is no longer used, and but one train is allowed in a block at the same time.

In operating the block system, either no signals at all are required, as in the case of the staff system; or, if operated by signals, the road must be very completely equipped with them. In the staff system, the engineer of a train receives at the entrance of a block a staff, which is equivalent to an absolute train order over that block and gives him right of track until he delivers it to the operator at the other end of the block.

In addition to the blocking of the road for the operation of trains, grade crossings, junction points, yards, etc., on a busy road, require their switches to be interlocked for safety and thrown by one operator from a tower. This necessitates a complete system of signals for the government of trains at such points, and, of course, this system must be in harmony with whatever form of signaling is adopted along the main line of the road.

In the following I will attempt to describe some of the systems employed, and the methods of signaling; and first I quote some definitions expressing the views of the American Railway Association on block signals, but make note that items 7 and 8 below are omitted from the definitions last issued.

(1) *Block*.—A length of track of defined limits, the use of which, by trains, is controlled by fixed signals prescribed and established for that purpose.

(2) *Block Signals*.—Fixed signals prescribed and established for the purpose of controlling the use of a block.

(3) *Home Block Signal*.—A fixed signal at the entrance of a block, to control trains on entering and using said blocks.

(4) *Distant Block Signal*.—A fixed signal of distinctive character used in connection with a home block signal to regulate the approach thereto.

(5) *Advance Block Signal*.—An auxiliary fixed signal placed in advance of a home block signal and worked in connection therewith.

(6) *Block Signal System*.—A series of consecutive blocks controlled by block signals.

(7) *The Absolute Operation* of a block signal system permits but one train at a time to occupy the block.

(8) *The Permissive Operation* of a block signal system permits under certain regulations, more than one train at a time to occupy a block.

(9) *A Telegraphic Block Signal system* is one which is operated manually, as directed by telegraph.

(10) *A Controlled Manual Block Signal system* is one which is operated manually, but which, by its construction, prevents the display of a "clear signal" while the block is occupied by a train.

(11) *An Automatic Block Signal system* is one which is self-operative, whether by mechanical, electrical, pneumatic or other device.

A block signal may or may not be of the same form as those used for interlocking or for train orders. The practice of roads in this country and in different countries varies greatly in this respect.

According to the practice in this country, the position of signals is most generally to the right of or directly over the track governed. This practice is not uniformly followed in Europe, however. It is a fundamental law of signaling, that, when out of order, signals shall go to the danger position, whatever that may be; that is, they should go to danger automatically.

The meaning of a signal may be conveyed either by color or by position. In this country the general practice requires that the meaning is to be conveyed by a combination of color and position. The three plainest colors are red, white and green; hence, these colors have been adopted for railroad signaling. In this country white is generally used to signify safety; green is used to signify caution, and is, therefore, used for distant signals, while red is used to signify danger and an order to stop. From the fact that when the glass of a night signal is broken, a white light would appear, it has been thought undesirable to use white to signify safety, and consequently, in England, safety is signified by green, danger by red, and a signal showing white is to be regarded as a danger signal. In England, therefore, there is no distinctive color for a distant signal. Red is used, and the fact that it is a cautionary signal is shown only by its location along the track. In France the same colors are used for signals as in this country.

These colors are generally obtained by lights with white or colored lenses.

Day signals, both in this country and in foreign countries, may be

colored disks, the same colors being used as at night. Colored disks are generally used in France. They are used also on a number of roads in this country. However, it is generally conceded that a colored arm, projecting from a post, is a more distinctive signal than a disk, except, perhaps, in tunnels. For this reason the semaphore signal is used very extensively in this country, in England and in Germany.

The most common practice in this country requires that the post be about 20 feet high, painted white, and situated to the right of the track governed by its signals. The semaphore arm projects to the right of the post and is painted red in case it is a block, home or train-order signal; or green if it is a distant signal. In the last case the end of the semaphore is generally notched. However, practice is not uniform, even in this country. In the case of roads with more than two tracks, semaphores are placed on bridges and are then directly over the track governed.

In a horizontal position, a block, home or train-order signal signifies danger, or "stop." Inclined at an angle of 45° or over, it signifies safety, or, in case of a permissive block system, if inclined at an angle of less than 45° , it gives a train permission to go ahead under control. A green semaphore signifies caution when in a horizontal position, and safety when in an inclined position.

More than two semaphores are often arranged on the same post where they govern over two routes. In this case the upper blade generally controls the high-speed route, and the lower ones govern the routes in order from right to left. However, this practice is not entirely uniform, even in this country.

In order to fully protect a junction or a set of switches at a station by an interlocking system with semaphore signals and to secure a prompt and safe movement of traffic, signals have become quite numerous.

To show their variety, the attached statement is appended :

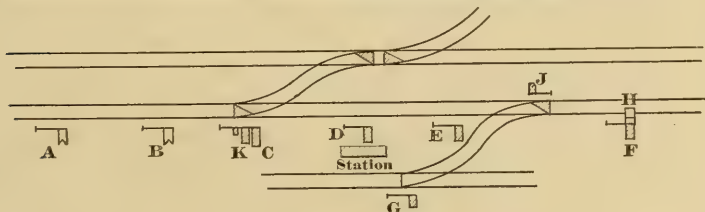


FIG. 1.

A.—First distant.

B.—Second distant, for suburban traffic or for very high-speed roads, say, ninety miles per hour.

C.—Rear home (a route signal).

D.—Home, protecting train standing at station.

E.—Starting, conveying order to start and covering siding switch.

F.—Advance. This is placed a train length in advance of siding switch to cover switching movements.

G.—Siding. This covers departure of trains from siding.

H.—Wrong track, governing west-bound movements on east-bound track.

J.—Shifting.

K.—Calling on signal. This signals trains to advance slowly past the tower for clearing home signal *D*.

The above list is given more especially to show how complicated a system of signals may become. It should be stated that the complication of signals is not looked upon with very much favor.

As intimated above, there is some difference of opinion as to the best form of signals. It is generally conceded that a very strong light, whatever its color, is the best for night. Some, however, wish to adhere to the position plan and go to considerable expense in order to illuminate their semaphores at night, as in the Koyle signal and the Union Switch and Signal Co.'s hollow box blade. There are others who think a disk is suitable for day, and confine themselves to the color method by day, and who are also able to use the same form of disk and the same colors as at night. Some recommend, for block signals, a form of signals different from that used for interlocking. This would allow of the use of a disk signal for blocking and a semaphore for interlocking. The Boston and Albany Railroad uses two white lights placed in horizontal position for danger, and two green lights placed in a vertical position for clear. The Old Colony Railroad has two red lights placed horizontally for danger and two white lights placed vertically for clear. In this way they secure position signals at night, just the same as by day by the use of the semaphore.

Having described the signals, it is necessary to describe their method of operation. In interlocking plants, both the switches and signals are controlled and thrown by an operator in a tower or signal station located generally near the switches. In case a mechanical device is used, a Saxby & Farmer or a Stevens machine is used, either in original form or as modified by recent improvements. These improvements have been very great in the last ten years. A lever is not only provided to throw switches and signals easily, but the switches and signals are all interlocked by a series of locking-dogs or their equivalent, so arranged on the machine that no switch can be thrown without its corresponding signal and that a signal, even for a desired route, cannot be given until all the switches have been safely placed for that movement. By such a machine, switches 1,200 feet distant from a tower in each direction can

be thrown by pipes of $1\frac{1}{4}$ inches diameter, which are used to transmit the motion ; and signals distant about 3,000 feet, on each side of the tower, can be operated by the use of double wires. I will not attempt to go into the details of these machines and their connections.

An improvement on this method of throwing switches and signals is obtained through the use of compressed air. In the system known as the Westinghouse electro-pneumatic, controlled by the Union Switch and Signal Co., both switches and signals are thrown by air under a pressure of forty pounds per square inch. The air necessary for this purpose is compressed by pumps located at or near the signal station, and is conveyed in pipes to whatever switch or signal it may be desired to operate. This switch or signal may be several miles distant from the tower. At each switch or signal is a cylinder, with a piston, and air is conveyed to the signal piston through valves, which are operated by electricity. In the case of the switch cylinders, the air acts on oil, which latter conveys the motion directly to the piston, the air valves being opened by electricity. With this system the operator has only to turn a small switch, no larger than an ordinary electric switch, in order to throw any switch or signal connected with the signal plant, covering, as stated above, several miles in extent. This system requires a plant for compressing air, careful laying of pipe lines and the necessary mechanism at the switches and signals to move them. It also requires a telegraph line, so that electricity can be used for opening the valves and for locking them. The switches and signals are interlocked, the same as in the mechanical plants already described, the interlocking device being located in the tower, but occupying a very small space as compared with that required for the mechanical device. In the tower is always placed a tell-tale apparatus, on which is reported every movement taking place in the track ; and this movement is not shown on the tell-tale apparatus until it is completed in track. Electric bells and annunciators, for showing the location of trains, complete the system. The Stewart Avenue Plant, Chicago, is the latest one of this system installed. By this plant, 86 signals, 37 single switches, 22 double slip switches and 22 movable frogs are thrown by a machine having only 90 levers and occupying a space of 5 x 24 feet. A mechanical machine, to do this same work, would require 187 levers, and the machine would occupy a space of 14 x 77 feet. All signals are lighted by electricity supplied from the power-house.

A pneumatic system, as described above, is also used for block signaling over long distances. The system is used at many important points on the Pennsylvania Railroad. At Jersey City three trains can pass over the same track out of that station within $1\frac{1}{4}$ minutes under the operation of this system.

This system is applicable to very large plants. It is too expensive

for small interlocking plants, or even for those of ordinary size. It is undoubtedly the most complete system of its kind at present in use anywhere.

In Italy, glycerine has been used to transmit motion for switches and signals, as also an unfreezing mixture of water; but the hydraulic pressure used there is from 50 to 60 atmospheres, and this pressure is too great for very successful use.

At St. Louis bridge a hydraulic pressure system was first used in 1883, controlling tracks along a distance of three miles, and operating switches on twenty-eight miles of sidings. This was not an entire success, however, and air is now used to transmit the motion, but hydraulic pressure is used at the valves. This plant consists of 108 levers, throwing 138 switches and signals, and handling about 131 trains daily.

Another system, striving for the same end as that of the Union Switch and Signal Co., is a new one recently brought out by the Electric and Auto-pneumatic Railway Signal Co., Rochester, N. Y., and now being tried. This is strictly a pneumatic system, but, in this case, not only are the switches and signals moved by compressed air, but the interlocking of the switches and signals is secured through the same means, and the pressure of air necessary for operating the switches and signals is only ten pounds per square inch. A plant of this form has recently been put in use on the Delaware, Lackawanna and Western Railroad at Buffalo, N. Y. The movement of the switches and signals is controlled by a small lever and a seven-way valve. It is through this peculiar valve that the interlocking is secured.

Electricity also has been used in interlocking apparatus; *i. e.*, electricity both for throwing switches and for throwing signals, as well as interlocking them. The Ramsey-Weir interlocking apparatus, which is being tried on the Cincinnati, Hamilton and Dayton Railroad, Cincinnati, is an example. The power is obtained from a gasoline engine operating an Edison dynamo of 125 volts, and a storage battery, which is charged every twenty-four hours by a dynamo working for eight hours. The plant, operated in this manner, consists of ten switches and ten signals. The cost of fuel for the engine is placed at seventy-five cents per day. The apparatus, as a whole, is very complicated and its success has not yet been entirely proved.

The most complete purely electrical system is the Siemens-Halske, of Germany. This system is used for blocking as well as for interlocking. The signals are operated by a Siemens machine producing an alternating current generated by the operator turning a crank. This system has not yet been introduced in this country.

Having described the various signals and their operating plants in interlocking, it is proper to take up the details of

BLOCK SIGNALING.

On very busy main lines the block system is required for perfectly safe operation; but the kind of system to be adopted depends upon the character of the traffic, and considerable study is necessary to determine what is necessary and best in any given case. The systems of operation are the train-staff system, the telegraph block, the controlled manual block and the automatic system.

The electric train-staff system is very much used in England, and is considered the safest for single track. The Webb & Thomson form requires, at every block station, an operator, and a patent staff machine, which is about 5 feet high and is provided with a slot to receive the train staves, which are each about 15 inches long. At the top of the machine are an electrical lock, an annunciator and a key for communicating with adjacent block stations. The construction of the machine is such that only one staff can be taken out of it at a time, and, having been taken out of the machine in the first station, the staff must be deposited in the machine in the second station before a second one can be issued from the first station. Likewise, Station 2 cannot issue a staff for a train bound for Station 1 if Station 1 has already issued one. The staves are readily exchanged between an engineman and a signalman on route. In case of moderate speeds a bag is used, with an apparatus working on the same principle as a mail crane.

Another machine on the same principle, but more compact, is Tyre's Train Tablet Apparatus. The working of the block is exactly the same as that above described, but in this case, instead of using iron staves, small iron tablets are used. An engineman, holding either a train staff or a train tablet, has an absolute right on the section to which it belongs, it being equivalent to an absolute train order; and it is utterly impossible for a train, moving in either the same or an opposite direction, to get upon the same block with another under the block rules.

The operation of this absolute block system requires no block or order signals whatever, but they may be used to give notice of staff.

The telegraphic block system calls for signal stations at the ends of all blocks, and the block signals should be controlled by signalmen only. The normal position of the signal should be at danger, so that they shall require clearing in order to allow a train to pass. Signals should be restored to danger after the rear of a train has cleared the signal station a distance of 100 yards. The operator at that station is then in position to report to the preceding station, or to the dispatcher, that that block is clear. In this system, either the home signal should be placed in advance of switches near the station, or a starting signal should be placed in advance of the home signal and in advance of all switches, this to be interlocked with the block signals and to be used for starting trains. The simple telegraph system secures no check on the operators.

The Mozier system, which is extensively used on the New York, Lake Erie and Western Railroad, is an improvement on the simple telegraph block. The block signals are arranged for three positions. A semaphore in a horizontal position by day, or a red light by night, signifies danger; the semaphore inclined upward by day, or a green light by night, signifies caution; and a semaphore inclined downward at an angle of 45° by day, or a white light by night, signifies safety. As operated on the New York, Lake Erie and Western Railroad, the cautionary signal is not used for passenger trains; in other words, passenger trains are run under an absolute block system, while freight trains are run on the permissive block system, using the cautionary signal. All trains are under the direct control of the dispatcher. The operator's key is locked with the signal, so that it cannot be used unless the signal is at danger. The operator sets his signal under the direction of the dispatcher, who orders red, green or white as desired on the approach of a train reported by the operator. The dispatcher signs his initials, and the operator repeats the order. To adopt this system over the old form of train orders required an increase of 40 per cent. in the number of train orders, but the orders are very short, and it is reported that the system is liked by both the dispatchers and operators, and that an increased amount of traffic is handled. No distant signals at block stations are used, and, therefore, an accident is possible in case of freight trains using the permissive block.

The Controlled Manual Block system requires that the operator shall not be able to give a clear signal for a second train until the advance block has been cleared. It requires, further, that all sidings shall be interlocked at the block stations. It is further recommended that a bell or other audible signal be attached to such switches in a block as may not be interlocked, so that information may be given to the train about to use such main-line switch to leave a siding when the block is clear. The use of the Sykes Block system, with all switches interlocked, covers these requirements. This system is in extensive use on the New York Central and Hudson River Railroad, and on the New York, New Haven and Hartford Railroad, as well as some others.

The Sykes system calls for an electric-locking device, enclosed in a small box, which is placed in the signal station at the end of each block, these instruments being connected together by wire. A miniature semaphore arm over the box shows whether the advance block is clear or not. In addition to this, an annunciator shows whether or not the signal lever is locked.

With three signal stations (*A*, *B* and *C*), *A*, having a train for *B*, signals him accordingly by bell. If *B* is ready to receive the train he presses a plunger in his instrument, which causes the words "Train On"

to appear in the opening in his instrument, the word "Locked" to disappear in the opening in *A*'s instrument and the word "Free" to take its place. *B*'s plunger is locked and remains so until the train has passed his home signal, while simultaneously *A*'s starting signal is unlocked. He lowers it and allows the train to go towards *B*. This action, however, brings forward the word "Locked" in *A*'s instrument. *A* then raises the starting signal to danger, and it cannot be lowered again without *B*'s permission. Before *B* can lower his starting signal, the train must pass an insulated section of track at his station, and he must go through the same action with *C* that *A* has previously gone through with *B*. Further, *B* is obliged to raise the starting signal to danger behind the train he forwards to *C*, before he can permit *A* to send him another train.

It is, therefore, an absolute block in every sense of the word.

In its most complete form, the system calls for home, advance and distant signals at each block, and requires the release of these signals to take place in the order : *home*, *advance* and *distant*. It further requires the electric control of outlying switches. This is accomplished by derails in every siding connecting with siding switch through one lever in a small hut at the switch, and an electrical lock is placed on this lever, which is controlled at the tower at the outgoing end of the block. The tower and hut are connected by a bell code. The detail is in use on both the roads above named.

On the New York Central and Hudson River Railroad, in order to secure the best possible service, a special cable is used for the wires in the system. It is an eight-conductor, aerial cable, suspended 12 feet above the ground on Western Union telegraph poles, with an intermediate pole, the cable being supported by a No. 6 iron wire.

In case of the failure of the electric line under this system, the operator on the New York Central and Hudson River Railroad is not allowed, under any circumstances, to unlock his Sykes instrument. But the operator, knowing that his advance block is in proper condition, allows a train to go forward under a written order, thus temporarily reducing the block from absolute to permissive.

The Sykes' system is used in the Fourth Avenue tunnel, Harlem. The disk signals here used are supplemented by torpedo-exploders and gong-signals. The torpedoes may be placed on the track ahead of a train and the gongs may, if necessary, be sounded by the action of the operator at any time during the passage of a train. Both of these signals are in harmony with the visual signals. Further than this, in the cabin is shown the position of all signals in the tunnel, and the condition of every light is shown by a simple device acting in such a manner that when a light is out the continuous electrical current is broken

by the contraction of two zinc strips placed close to the light. In this case, the automatic signals are used in addition to the Sykes system, the automatic blocks being properly overlapped, and all these visual signals go to danger upon the passage of a train, these automatic signals being operated through a track circuit. As a double check on the entire system, all the distant automatic signals are controlled by the wire circuit, and home signals by the track circuit. Under ordinary circumstances, therefore, the automatic system is used in this tunnel, and the Sykes system is put in use whenever, from any reason, the automatic system fails.

Before the New York Central and Hudson River Railroad adopted the Sykes apparatus, it used extensively two forms of automatic signals—the “pneumatic,” and the “Hall”—but it was found that these automatic signals could not be worked under absolute rules. Engines had to be allowed to pass the block signal at danger, provided they waited a time interval; and any automatic signal must have such a rule. It was for this reason that the Sykes system was adopted on the New York Central and Hudson River Railroad.

The Siemens-Halske system, already mentioned, is exactly similar to the Sykes in its results. The most important difference between the two is in the use of the electric current generated by the operator, instead of the battery circuit, to which, of course, there is some liability of accident in case of storm. In this system the power necessary to change a block is generated by the operator, who turns a crank at his locking instrument, twenty-one alternating currents being required for this purpose. This block system is not in use in this country at present.

Another form of controlled block system is the “Lattig,” advanced by the National Switch and Signal Company, and claimed to be applicable to both single- and double-tracked railroads. By means of the adaptation of the electric slot to the signal, it is automatically set at danger by the passing of a train, and cannot be lowered by the signalman until the train has passed on to the next block. In other words, the signal is automatically set at danger and is so maintained, but is set to safety only by hand. The system may be used either with the wire circuit or with the track circuit. The latter, of course, gives the most complete protection while it is worked properly. In this system the current is always on. This requires considerable expense in maintaining batteries and they are liable to get out of order. Further, the electrical slot arrangement attached to each signal, in order to secure an absolute block, is a somewhat delicate apparatus and liable to get out of order. The system cannot be regarded as proved.

We will now pass to the *Automatic Block system*. To this system belongs the Westinghouse Pneumatic-Automatic, extensively used on the

Pennsylvania Railroad, also used on the Chicago, Burlington and Quincy Railroad; and on the Central Railroad of New Jersey. Fig. 2 shows the arrangement of signals on the Central Railroad of New Jersey.

In brief, the track is arranged with double or overlapping blocks, separate posts being furnished for each track. There are two blades on each post, the upper one red, with red lamp at night, and the lower one green, with a green lamp at night. When either of these blades is lowered to a safety position, a white light is shown at night, and an engine-man passing a signal with the red arm lowered to safety and a green arm at danger position, must slack up and be prepared to stop at the next signal. The blocks are short, say, about one mile in length. The lengths of the blocks would naturally vary, with the traffic requirements of the road.

In this device the track circuit is used, consequently a block signal cannot go to safety while a train, or any portion of it, is in the block. This end is secured by the fact that the signals are locked to their danger position by electricity, and are placed in the circuit with the track. The



FIG. 2.

power to move the signal arms is derived from compressed air, conveyed in pipes along the track. This compressed air acts upon a piston enclosed in a cylinder placed at each signal, as described in detail under the head of Interlocking. The track circuit is so arranged, in passing through switches, that the circuit is not complete unless closed to the main line. Therefore, the signals cannot go to safety unless all switches are properly set. The system is a very complete one, but is expensive and is generally considered to be out of the reach of a single-track railroad. Of course, it is possible for these automatic signals to fail, from two causes:

(1) From any defect in the pipe line or in the cylinder attachment at the signals.

(2) From any failure in the working of the electric current.

In case of either of these failures, however, the signal goes to danger, in which event the train must proceed under special rules.

The Electric and Auto-Pneumatic Railway Signal Company, of Rochester, N. Y., is attempting to introduce a pneumatic block system carrying out its principle, which is described under the head of Interlocking. This system uses compressed air, both for moving the signals

and for locking them; also, for locking switches, and it does not use the electric circuit, and, therefore, does not attempt to protect the track so thoroughly as does the device of the Union Switch and Signal Company, already described.

The Hall Signal Company has a very complete automatic signal system extensively used on the Illinois Central Railroad. It is used also on the New York Central and Hudson River Railroad, New York, New Haven and Hartford Railroad, the Central Railroad of New Jersey, and many others. It is purely an electrical device, electricity being used to throw all signals. The signals are disks in three colors—red for danger, green for caution and white for safety. The night signal shows the same as the day signal. The block signals may be placed at any desired distance apart, and may be overlapped as much as may be thought necessary for safety on any given road. The signal may be operated by a wire circuit, in which case instruments, operated by the passing of a train to close the electric circuit, are used along the track. These track instruments have been proved to be a very complete and unfailing device.

A train, entering a block, passes a block track instrument which breaks the current, and the signal falls to danger. The same train, passing out of this block, goes over a clear-track instrument, which closes the circuit and raises the first signal to safety. The current is, therefore, closed except when a train is in the block or when a switch is open in the block.

In this scheme, therefore, the normal position of all signals is at safety. A signal will always drop to danger in case a train is in a block, or in case of an open switch or an accident to the apparatus.

The Hall signal may, however, be operated by a track circuit. In this case the rail circuit is made very complete by the detail of the wire fastenings used at the joints, and the rail current is carried through switches by means of a special switch instrument. The track is divided into blocks, the rails of which are insulated from each other. In the normal safety scheme, while there is no electrical contact between the two lines of rail in a block, the block signal is at safety. A train entering this block short-circuits the track battery through the wheels, and the signal falls to danger; or, in case a switch is open in the block, the signal circuit is broken and the signal falls to danger. A train passing out of this block causes the local signal battery to restore the signal to safety.

In the normal danger scheme, signals stand at danger, and are cleared only when an approaching train reaches a given point in advance of the block signal and in sight of the engineer. It is again dropped to danger when the train reaches it, and is locked so that it

cannot be cleared by a following train until the first one has passed out of the block and is under the protection of the succeeding signal.

This last scheme is a very complete and effective system of automatic block signaling, and costs but about one-third as much as the pneumatic-automatic system. Applied to a single-tracked railroad, its working is shown as follows (Fig. 3):

Head of train at *A* blocks opposing signal 2.

Head of train at 1 blocks signal 1 and opposing signal 4; opposing signal 2 remains at danger.

Rear of train at 2 clears signal 2; signals 4 and 1 remain at danger.

Head of train at 3 blocks signal 3 and opposing signal 6; signals 1 and 4 remain at danger.

Rear of train at 4 clears signals 1 and 4; 3 and 6 remain at danger.

Head of train at 5 blocks 5 and signals in advance, signals 3 and 6 remaining at danger.

Head of train at 6 clears signal 3; 5 remains at danger, etc., etc.

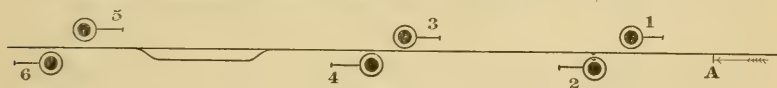


FIG. 3.

Upon a road which, under the controlled manual block system, required operators four miles apart to handle the traffic, the introduction of this system would enable the placing of the operators twelve miles apart, each operator having control of the signals at a passing siding through an interlocking board and tell-tale at his station.

The extension of this system announces trains approaching all block stations, passenger stations, road crossings and switches.

In attempting to make any comparison between the controlled manual system and the automatic system, it is generally considered that the manual signals are more liable to be obeyed by enginemen than the automatic, as disobedience of the former leads to a report from the operator, while no reports are possible in the latter case. In the case of accident to the automatic system, it is inert; while in case of accident to the manual system men are at hand to take action to provide against accident and to straighten out obstructions to traffic. However, the cost of operating the manual system is greater than that of the automatic, in some of its forms (such as the "Hall"); but, further, the automatic is applicable to a more complete protection of the track, road-crossings, etc., than is possible with the manual.

As compared with any telegraph or train-order system, block sig-

naling is generally considered more economical, as it affords a better protection of the track, and avoids danger of small rear collisions, and this to such an extent as to cover the cost of the blocking.

The devices mentioned show methods of protecting track and securing a constant check upon operators. The check upon engineers is not quite so complete, although their obedience to signals is in many cases assured by derailing switches, and in other cases, as in tunnels, by the use of automatic torpedoes or gongs. Still further advancement is constantly being effected. The Electric and Auto-Pneumatic Railway Signal Co., of Rochester, N. Y., who are introducing a pneumatic block system, already described, have, in connection with their system, a shoe, which is placed between the rails opposite a danger signal, and which projects above the rail whenever the danger signal is not at safety. If, therefore, an engineer passes a danger signal, a projection from the engine, connecting with the air-cock of the air-brake system, strikes the shoe, and this action results in the setting of the brakes. This system is not fully proved.

The Rowell-Potter automatic block signal, which was used on the Intramural Railway, Chicago, uses a track-circuit system of block signals, and has also a bar which projects above the rail whenever the signal is at danger. This comes in contact with a rod extending below the front truck of the engine and provided with rollers on its end. This, striking the raised bar, opens the air valve and applies the brakes.

Of other devices many have been brought forward, but thus far not extensively used. One of these is the Kinsman Block system. It is a purely electrical device, and claims to stop trains without the agency of the engineer in case the block in advance is not clear, or in the event of an open switch or broken rail in the advance block. In this system the track is divided into blocks two miles or less in length, and the track-circuit system is used. At the ends of the block is a guard rail, which is electrified in case the block controlled by it is not clear in every respect. An electric signal, displaying a disk, may be used in addition, if desired; but with this block system the visual signals are not regarded as absolutely necessary. Each engine is equipped with an arm, suspended between the wheels and adjusted to press against all guard rails, like the flange of a wheel. This arm is electrically connected with an instrument in the engine cab. The latter is directly attached to the air-brake pipe, and this, in turn, is connected with the cylinder of the throttle rod. In case an engine, so equipped, reaches an obstructed block, the suspended arm of the engine takes a current from the electrified guard rail, and the electrical instrument in the cab first acts independently of the engineer, to shut off the steam, and, by opening the air-valve, puts on all the brakes of the train.

The device in the engine cab is, I think, quite complete. The guard-rail device is not yet proved, and, I think, is inferior to the inducing magnets of the Wiley system. The signal recommended in connection with this system is not very good, but it is claimed that the engine equipment can be used with Hall signals, if desired.

This block system was first introduced in 1891. Experiments are now being made on three miles of the New York, Susquehanna and Western Railroad, and on twelve miles of the Chicago, Milwaukee and St. Paul Railroad. On the latter road it is reported by the railroad people that, on account of the electrified guard rails, the experiments are not yet wholly successful. In cost, this system does not vary much from the "Hall" System.

The Wiley Electric Block Signal system, with which the inventors are experimenting to a small extent on the Norfolk and Western Railroad, divides the road into blocks from one to five miles in length, and the wire-circuit system is used, requiring circuit-breakers in the track at each block. Its operation is similar to that of the Hall system wire-circuit, but it is probably cheaper in maintenance as well as in first cost. The signal, in its first form, is inferior, but the makers claim to have improvements under way.

This system may include an alarm signal bell in the cab of all engines, the bell being so arranged as to be sounded in case a danger signal is passed. Inducing magnets, located in the center of track at each signal, are energized whenever the signal is at danger, and similar magnets placed on the engine and suspended four inches over the rail, receive the current, which is conducted to the cab, where it serves to ring an alarm bell. This method of transmitting electricity from the track to the cab of an engine, seems to me to be the most complete I have yet seen, and superior to the Kinsman plan.

The devices last named require special equipment of every engine on the road; and so far they have not met with any very great favor among railroad men, it being feared that engineers would depend wholly on such signals as would be received in the engine cab, instead of being guided by track signals.

In conclusion, I have only to say that new devices and improvements in signaling are constantly being introduced; that many of these have merit, and that haste in adopting any given device is never expedient.

DISCUSSION.

MR. G. R. HENDERSON.—I would like to ask a question regarding the old staff system, of which Mr. Churchill spoke. On a road, locked electrically or otherwise, how are the staves to be carried from one end of the section back to the other, and arranged so that other sections can take them up? Also, was there not some system used before the application of electricity?

MR. C. S. CHURCHILL.—The staves work exactly the same as an electrically-locked staff, except that there is no check or lock on the operator issuing. There is more than one staff—probably some number of staves. The trains running in the opposite direction bring them back.

MR. M. E. YEATMAN.—I think I can explain the system which Mr. Henderson has in mind. By the original staff system it would be impossible to work unless trains were running alternately in different directions, one train taking the staff and the other train bringing it back; but, of course, this rule is absolutely impracticable for general use, and it was very soon superseded by the staff and ticket system. Only one staff is used, but at each end a certain number of tickets or train-order forms are kept in a box, the key of which is attached to the staff, and it is therefore impossible for an operator to issue a ticket clearing a train over a section unless he has the staff. If he knows that two trains are passing, running in the same direction, he gives a ticket to the first and the staff to the second. After these two he could not send any more until the operator had sent the staff back over the section. The operator at the other end might have three trains. This, of course, would necessitate his giving a ticket to the first, a ticket to the second, and the staff to the third. This system would require electrical communication so that it might always be known what was coming. It requires something corresponding to our central dispatcher system, and it was in general use for single track roads when I was familiar with English train service.

THE CHAIRMAN.—Mr. Churchill, I notice that you express no preference. You, no doubt, having gone through a study of all, have arrived at some conclusion as to which is best.

MR. CHURCHILL.—I stated that each of these systems is applicable to different conditions of a railroad. For instance, it is an open question between the Sykes system and the Westinghouse Pneumatic system on the New York Central Railroad and the Pennsylvania Railroad. There are two opinions. The New York Central uses the Sykes, and the Pennsylvania Railroad the Pneumatic. Each, as a matter of policy, would

certainly back its own system, and I think the results are probably about equal in both cases. The Sykes is rather the cheaper of the two.

THE CHAIRMAN.—The Pneumatic, I believe, is the oldest system of automatic electrical signaling.

MR. CHURCHILL.—It preceded the Hall, although the Hall was the first electrical device. They have kept right alongside. I went over two sections of the New Jersey Central within the last six months. One of these is equipped with the Pneumatic and one with the Hall, consequently, I had a good chance to compare the two, and there is this to be said about them: With the Pneumatic, there is an air line to maintain. You are obliged to have a system of pipes to conduct the air for operating these signals, and an electrical system maintained to lock and unlock them, the track circuit being used on this road. When you come to the Hall, you have the track circuit and electricity operating the signals, but the motive power is electricity; so that, while in the Pneumatic we have to maintain not only the electricity but the air, in the Hall we have to maintain the electricity alone.

THE CHAIRMAN.—Where the track is the instrument for carrying the circuit, what is the effect of a broken rail?

MR. C. S. CHURCHILL.—The signals would come to danger.

THE CHAIRMAN.—And remain at danger?

MR. C. S. CHURCHILL.—Yes; for the protection of the train.

MR. W. W. COE.—That would hardly be considered objectionable when a broken rail is there.

THE CHAIRMAN.—You have, no doubt, gone over a broken rail many a time.

MR. C. S. CHURCHILL.—Where the rails are not badly broken, and where the ends remain together, it would not affect the circuit; that is, provided you have a generally good track.

THE CHAIRMAN.—You think the principal difference between the two systems is in the cost of maintenance?

MR. C. S. CHURCHILL.—Between the two systems the first cost is the principal difference. The Pneumatic system is all right on a two- or four-track railroad, but would ruin a single-track railroad.

MR. W. W. COE.—Suppose the single-track road was going to grow—was in a progressive form?

MR. C. S. CHURCHILL.—It would cost something to locate it—something like \$1,200 per mile for the Hall, as against \$4,000 per mile for the Pneumatic.

MR. W. W. COE.—Two systems, one on single track and another on double track, would not do?

MR. C. S. CHURCHILL.—Not perfectly; still, they are so used, as in the case of the Hall and the Pneumatic on the New Jersey Central. I interviewed an operator there, and he expressed the opinion that there were fewer failures with the Hall than with the other. Understand, by failure I mean only the signal going to danger, owing to some defect in the signal plant. The blocking of the traffic amounted to but very little with either system.

MR. W. W. COE.—As I understand it, an engineer can accept a signal after it has been placed, and it is not required that he see it as it is being turned?

MR. C. S. CHURCHILL.—Well, he does see it in its normal condition. He accepts the signal as given, because, in case of trouble, it comes to danger automatically. I think the railroad people can see that the two systems are very nearly equal in their results. I mean as regards their automatic operation.

MR. SOULE.—I think there is one advantage that ought to be credited to the Westinghouse Pneumatic system, and which Mr. Churchill has not mentioned, and that is this: A great many signal engineers and practical railroad men have come to the conclusion that the semaphore signal is the only decent and acceptable form of signal for a railroad. Now, I do not think that any full-sized semaphore signal, such as is represented there, has ever been successfully operated by electricity, unless enclosed in a glass case and made on a reduced scale, and, in order to reduce its weight and inertia so that it can be operated by electricity and still have the semaphore of good size, it is necessary that the weight be reduced by having aluminum wire frames, with flannels or cloth stretched over them, and the whole enclosed in a glass case, and even then the glass case is likely to be obscured by rain, snow and ice, and the chances that the engineer will get a correct interpretation of this signal are correspondingly reduced. This must be considered in comparing the Pneumatic and electrical systems. The possibility of having a semaphore signal of any desired size, with a fixed and positive action, is an immense advantage in favor of the Pneumatic. It is getting to be not so much a change in color, as a change in position, which shall determine the meaning of the signals. I was quite familiar with railroad signaling up to three years ago. But Mr. Churchill's paper has made me realize that this is a progressive art—that it is going forward. I used to keep up with all of these devices, as mentioned in the mechanical papers, until the past three years, when I have not had the time for so doing. On the Pennsylvania Railroad I was identified with rail-

road signaling when it first began to be a serious question. The first effort they made to introduce an interlocking apparatus was when they sent to England, in 1874, and contracted for a track-signaling apparatus for the tracks at a junctional point, a simple double-track junction and cross-over. The apparatus was made in London, shipped over here and set up and put in operation by English mechanics. This gave an impetus to American inventors, and Towsey & Buchanan came to the front with their device. By 1876 the New York Central had constructed and put in operation four of these devices. When the Pennsylvania Railroad was getting ready for the Centennial, it was constructing tracks and bridges, but neglected signaling until the last moment, when I was detailed, on the 4th of March, to take up that problem, and was sent to Philadelphia in a hurry. The next day I was told that they wanted seven of these interlocking apparatuses, and that they were to be put in operation by the 7th of May. The General Manager, Chief Engineer and myself went over to New York, and the New York Central officials took us about and showed us all the interlocking apparatuses, and I was left there to study the subject. It was agreed that there was no time to order any apparatus from England, no time to undertake anything novel, and so we decided to avail ourselves of this system, and the New York Central people very kindly consented to lend us all the patterns. After taking a few castings for their own use, the entire outfit was shipped to Altoona, and got there by the 10th of March, and within these two months, before the 7th of May, all of the seven interlocking apparatuses had to be mapped out, made and got in running order. That apparatus was deficient in one essential principle. It did not include the feature of preliminary locking. That is, the modern apparatus is so made that as soon as the operator grasps the handle and closes his hand, so as to draw in the latch of the handle, the locking is accomplished preliminary to moving the lever. This simple grasping of the handle accomplishes the locking. Whereas, with this old style, the locking was not done until the end of the stroke. If certain others are to be unlocked, this is not done by the preliminary movement of the latch handle, but that unlocking is done when the latch snaps into the notch at the end of the stroke. Now this apparatus was deficient in that respect, and did not catch the principle of preliminary locking and the moving of the unlocking mechanism. When you were moving the lever, which was so arranged that you were moving that portion of the apparatus upon which it acted, you had no proof that it was unlocking until the stroke was completed, instead of at the outset. Consequently, every one of them put on the Pennsylvania Railroad in 1876, and some of them put on in two or three subsequent years, have been taken out and replaced by modern interlocking plants, where the principle of preliminary locking is carried out.

THE CHAIRMAN.—We are obliged to Mr. Soule for his interesting history of railroad signaling on the Pennsylvania Railroad. It may be that Mr. Coe could add to it.

MR. COE.—It was very certain in keeping trains apart, but sometimes delayed the movement of the freight.

MR. R. H. SOULE.—I stated that there were seven interlockind plants of this pattern. This was originally intended, but a party named Burr, from New York, a lawyer, patentee, and a very clever fellow, inventor, and so on, cropped up, with a proposed system of interlocking and secured consent to put in a plant at one of the double-track junctions. It was very crude, but in all essential features was pneumatic—with a reservoir for the storage of air, and a system of piping running to all the switches and signals. There were no electrical features anywhere. There was a double line of pipes, a supply and return pipe, to and from each switch and signal, and the thing was operated quite successfully. Two or three disasters occurred, nothing serious, however. This was the first attempt at the pneumatic operation of signals and switches, and he got some pioneer patents, which resulted in litigation with the Union Switch and Signal Company, in which he was victorious, so that they had to make a settlement with him and bought in the patents, some of which are engrafted in their plant of to-day.

THE CHAIRMAN.—Mr. Churchill, I would like to ask whether the tendency is not to disregard colors for signals, and if the position, rather than the color, is not relied on?

MR. C. S. CHURCHILL.—Well, that is a mooted question. I think that nearly every railroad will agree to go by the position of the signal during the day, and by the color at night. About a month ago I answered a lot of questions propounded by the Railroad Association of America, and about two days ago received advice of the replies. Replies from thirty-two of the roads were received, and, if I remember aright, twenty-eight were in favor of the semaphore signals by day and of color by night.

THE CHAIRMAN.—Was it not then suggested that if the use of color by night were adopted, red would appear white to a certain extent, when snow was on the glass?

MR. C. S. CHURCHILL.—I think this point is strained. A good red light would show red, even if the snow was on it. Four of the roads wanted a green light for safety, as in the English system, the argument being that if a red light were to break a white light would appear. I do not think that the best glass is liable to break, and, even if it were to

break, it would not be liable to break so badly in one night that some of the red pieces would not be left there to show a red signal.

Another argument is, that in approaching a town, an engineer might mix up the town lights with the signal lights and possibly take a town light for a safety signal.

I think that if the make of lens is considered, and if you have a good, strong lens (I think the N. and W. R. R. switch lens in the West-lake lamp is an excellent one), there is no danger of mistaking it for a town light, no matter of what kind, and any good strong lens, carefully put in, produces the same effect. But it is a mooted question, railroad men are still discussing it, and I do not know how it will be decided. You see what it has led to in England; two colors for three signals. I think it is a great mistake to compel an engineer to remember two signals, both showing a red light, which is a danger signal in one case and a distant signal in the other. He may turn to fix his engine just as he is approaching a distant signal, and, by the time he looks up, he may have passed it, and he does not know whether it meant safety or not. Then when he comes to the danger signal, he cannot tell, unless he knows all about the country, whether it means danger or caution, and he is simply obliged to hold his train. If there is to be any change at all, we should still have three lights for the three signals, danger, distant or caution, and safety. In your first question, you asked about the comparative merits of the systems. It might be well to state here that the Pneumatic is better than the Hall in that it enables the operator to throw any switch in a block. This is a great advantage. Mr. Soule's point about these signals has, of course, considerable merit, and yet you will find, as I brought out, that in the tunnels in New York they use disks in preference, and the New York Central people write me that they will stick to the Hall, that, after using it, they find it answers their purpose better than any other automatic signal. Again, take a road like ours (the Norfolk and Western Railroad) a single-track road, with double-track work going on. It is not necessary to equip the whole line with a device like the Hall; or with a Pneumatic, at a great expense. To secure greater safety on a road with a telegraph block, like ours, you can make your block more rigid than at present; make it an absolute block, and then check your operators by using the Sykes system. The Johnson people are very enthusiastic in the praise of their system (the staff), but they admit that theirs is only for a single-track railroad, and we are double-tracking, so that the most progressive plan may be to put in the Sykes. When you desire to add automatic signals, you can do so, and still not throw away any of the plant then in use.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Wood Pavements in Australia.

Apropos of the valuable matter on road construction contributed to this number of the Journal by our new member, the Association of Engineers of Virginia, it may be of interest to quote as follows from a paper on "The Evolution of the Modern Road," read before the Victorian Institute of Engineers, in November last, by Mr. A. C. Mountain, City Surveyor of Melbourne, Australia.

"Wood-paving was first laid in Australia in 1880, when an experimental section was laid with various kinds of wood in King street, Sydney. The main principle of obtaining a firm and impervious foundation of concrete was adopted, and a $\frac{3}{4}$ in. joint between the rows of blocks was provided for. This latter was determined on at the desire of some of the authorities (who were naturally anxious to prevent a failure of the unknown material through slipperiness), but was soon found to be not only unnecessary, but detrimental to the life of the road, as it enabled the toes of the horses' shoes to work on the arrisses of the timber until, in time, the effect of a corduroy surface was produced, making the roadway very noisy. In 1885, perceiving this, I reduced the joint to $\frac{1}{2}$ in.; and, in 1886, still more narrowed it to $\frac{3}{8}$ in. As a matter of fact, experience has shown that, with proper attention to cleanliness, there is not much more danger, on the score of want of foothold, with hardwood than with sets, and that the joints may be regarded as adding but little to the safety of the road. In practice the paving in Melbourne has been laid for some years past with $\frac{1}{4}$ inch joints, with the exception of one section where the blocks were simply tarred and laid close together; but the great expansion of our red gum renders it doubtful whether there be any real advantage in this method.

The blocks are sawn in lengths of six inches out of 9x3 planks, and are laid on a foundation of good Portland cement concrete, varying from 6 to 9 inches in thickness according to the nature of the ground, brought to the proper gradient and convexity, the latter generally one in fifty, and worked smooth on surface by means of a "floating" or rendering of cement mortar. The length of six inches was chosen for the blocks, not because it was essential to have that depth to ensure a firm and substantial coating to the street, which it had been demonstrated can be obtained with a 4-inch block, but in order that when much worn on the top the blocks may be cut down in length and re-used on the work.

"As regards the cost of wood-paving, the latest work done in this city has been carried out, including excavation and 6 inches of concrete foundation, at the rate of 16s. 6d. per square yard. I have no knowledge of any similar work that has been done so cheaply. Even at this price, which is about four times the cost of a good macadamized road in Melbourne, it will readily be perceived that ultimately the wood becomes the cheaper pavement, if its durability is such that the saving in annual maintenance (as

compared with the cost of keeping the macadamized road in order) be more than will cover the difference between the original outlay cost of the two materials. This is entirely apart from the question of public comfort, cleanliness, and wear and tear on horse and vehicle, which must surely be valued for something."

Béton Armé.

A system of construction bearing this name (which may perhaps be freely translated "reinforced Beton," or "iron-clad Beton,") appears as a rival of the Monier system. Its inventor is M. Hennebique, a French engineer, and its chief claim appears to be that the materials used, the concrete and the iron, are exposed to those stresses which they are best adapted to resist, the iron, in beams, being placed chiefly in the lower part of the section, while the communication between the upper and lower portions is secured by the use of thin iron plates placed vertically, or nearly so, in the mass, after having been coated with a thin layer of cement mortar.

Another advantage claimed for the system is that iron in common and easily obtainable forms, such as flat, round and square bars, can be employed, thus securing cheapness of construction.

A number of buildings on this system have been constructed in Belgium, France and Western Switzerland, and a warehouse is now being built at Lausanne.

Electric Railways with Underground Conductors.

In these days of the almost universal sway of the trolley system, it may be interesting to note that the Blackpool Tramway, installed in 1885, has ever since been using underground conductors.

As originally installed, the slot was placed midway between the rails, but Mr. Holroyd Smith, in reconstructing the system, places it under one of the rails, which is divided for the purpose. The return circuit is through the rails, which are reinforced, where necessary, by a wire with which they are connected at intervals.

When the track is double, the conductor is placed under each of the inner rails, and in order to adapt the motors to this condition of things the collector is made movable transversely of the car.

Large cars recently furnished for this road have two four-wheeled trucks, with a motor on each truck, and eighty-two seats, including a considerable number on the roof.

The road is about two miles long, and, during the last seven years, has been operated by a company, but it has now passed under municipal control.

In first cost, the Holroyd Smith system is said to be more expensive than the trolley, but cheaper than the cable, while its cost of operation is fairly comparable with that of the trolley system.

The four lines of the Siemens-Halske underground-conductor system in Buda Pesth have been in operation since 1887.

Progress of Electrical Engineering.

It is significant of the progress recently made by electrical engineering that whereas only 32 of the 475 pages of the Association's Index to Cur-

rent Literature for the years 1884 to 1891 were devoted to electrical matters, about one-fourth of the items in the index for the current number pertain to such subjects.

Electrical Towing on the Bourgogne Canal, France.

The motive power for this work is derived from turbines established at two locks upon the canal. These turbines make one hundred revolutions per minute, and act directly upon the dynamos through a horizontal shaft. The current is conveyed to the line through three wires of 8 mm. diameter, supported upon poles and upon cross wires.

The towing boats are 49 feet long by $10\frac{1}{2}$ feet wide, and draw less than 18 inches of water. They take the current from the line by means of trolleys at the ends of poles, which are made nearly 25 feet long in order to provide against the oscillations of the boat.

A battery of 250 accumulators has been installed at one of the power houses with a view of storing the force of the fall while the boats are idle, and delivering it up again when they are in motion. It would appear, however, that their installation was hardly justified, especially in view of their heavy cost, which amounted to about \$3000. The cost of the entire electric towing plant was about \$27,000.

From September 1, 1893, to April 1, 1894, there were transported by electricity 81,000 tons in 997 hours, at a cost of \$1180, while during the corresponding period of the preceding year 78,600 tons were transported by steam in 917 hours at a cost of \$1600. The comparison, however, covers a period of time too short to warrant the drawing of definite conclusions.

Improvement in the Roasting of Carbonate Iron Ores.

At the meeting of the French Society of Civil Engineers on February 1st, Mr. S. Jordan described an improved furnace by which he had greatly reduced the cost of roasting carbonate iron ores. Mr. Jordan found that in Cleveland, England, and in various places on the continent, from 30 to 40 kilograms of fine coal were required for the roasting of 1000 kilograms of raw carbonate. This appeared highly economical when compared with the consumption of coal in the calcining of limestone, which required a consumption about $3\frac{1}{2}$ times as great. Mr. Jordan, however, succeeded in constructing at Bilbao a furnace where the consumption of coal per thousand kilograms was reduced from 30 or 40 to 4 kilograms. The furnace is nearly cylindrical, 4 meters in diameter and about $3\frac{1}{2}$ meters high. It furnishes daily about 60 tons of roasted ore from 85 to 86 tons of crude ore.

In the construction of this furnace Mr. Jordan sought to provide that the ore should at first descend uniformly and in horizontal layers, becoming gradually warmed until it arrived at the zone of combustion, where the disengagement of the carbonic acid is completed. Below this level the resulting protoxide combines with an additional supply of oxygen to form peroxide.

In a larger plant now being constructed, the previous reduction of the fuel to a gaseous form is entirely abandoned.

The "Wobbling" of the Earth's Axis.

A writer in the Boston Journal discusses the facts recently brought out by astronomers and showing that the position of the poles upon the surface of the earth shifts through a small orbit in a period of something over a

year. The writer in question argues that, as the latitudes of points on the earth are thus shown to vary from one year to another, the locations of political boundaries that are fixed on parallels of latitude must vary likewise, and gives statistics of the area of land that must be in the United States in one year and in the Dominion of Canada in another year. Mr. N. Spofford, of Haverhill, Mass., who has been re-running the boundary between Massachusetts and New Hampshire, writes to the Haverhill Daily Bulletin to assure its readers that after a line has been once properly surveyed and monumented, any cavorting around of the parallels of latitude must be on their own responsibility.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Massachusetts State Board of Health. Report upon the Metropolitan Water Supply.

In accordance with an act of Legislature approved June 9, 1893, the State Board of Health has been considering the question of a water supply for the city of Boston and its suburbs within a radius of ten miles from the State House, and for such other cities and towns as, in its opinion, should be included in connection therewith.

The report of the Board is accompanied by those of the chief engineer, Mr. F. P. Stearns, and of the consulting engineer, Mr. Joseph P. Davis.

The cities and towns which it is believed desirable to include in the scheme have an aggregate population of 848,000.

The three sources which seemed worthy of critical examination are Lake Winnipiseogee, the Merrimac, above Lowell, and the Nashua, above Clinton. The last named was selected as in all respects decidedly preferable. An additional supply from the Assabet, Ware and Swift Rivers is contemplated in case of necessity.

The scheme involves the construction of a masonry dam 145 feet high and 1250 feet long, impounding water to a depth of 125 feet, on the Nashua River about a mile above Clinton. The lake above this dam will have an area of 6.56 square miles, an average depth of 46 feet, and a capacity of over 63,000 million gallons. The Swift River, if utilized, would require a still more formidable dam, 144 feet high, impounding a lake with an area of 37 square miles.

Steam Power and Mill Work. Principles and Modern Practice. By George William Sutcliffe, Mem. Inst. C. E. Whittaker & Co., London and New York, 1895. 877 pages, 5 x 7½ inches, and index. Illustrated. Price, \$4.50.

While this work forms one of what is called the Specialist Series, it would seem to be designed rather for the enlightenment of those not previously conversant with the subjects treated, and for this purpose it seems to be admirably adapted.

Beginning with the first principles, those of heat and work, and passing on to the discussion of fuel and combustion, calorimeters, storage and treatment of coal, the construction and behavior of boilers, etc., the author takes up the consideration of steam, its various properties, and its employment in the steam engine, the anatomy, physiology and hygiene of which are then treated.

The author then proceeds to consider, somewhat more briefly, various matters connected with machinery, such as toothed, belt and rope gearing, pulleys, shafting and its appliances, friction and lubrication, the corrosion of metals, hoisting apparatus, engine and machine foundations, and the design, choice and maintenance of engines and machinery.

The work is satisfactorily, though none too fully, illustrated, and the treatment is conscientious and the language clear.

City Engineer of the City of Omaha. Annual Report of the ——. December 31, 1894.

In the previous report, dated January 1, 1894, and noticed in the Library for March, 1894, the matter of prime importance seemed to be the question of constructing a canal for the purpose of bringing water power to the city, with a view to rendering the latter a great manufacturing centre. Judging from the present report, this question seems to have lapsed into innocuous desuetude, and the attention of the City Engineer is now devoted chiefly to the comparison of different forms of street paving. Mr. Rosewater, like some of his brethren farther east, has come into conflict with the disposition to draw specifications restricting the use of asphalt to that from one particular locality, and he makes no secret of his objection to the practice.

During the year, 14,000 lineal feet of sewers have been constructed, at a total cost of over \$21,000. Little or nothing has been done in the way of street extension.

Mr. Rosewater claims that Omaha is the only city of its population in the United States that does not own its water works, and that the city can never secure the full benefits that it ought to have from a water-works system until it is the possessor of its own plant. He produces a diagram based upon Mr. Freeman's experiments and showing the height of discharge of effective fire streams through various lengths of hose and other nozzles of different sizes.

Conversion of Measurements in Different Units. Forty-three Graphic Tables and Diagrams for the ——. By Robert H. Smith, Assoc. Mem. Inst. C. E. London: Charles Griffin & Co. 1895. Price, 7s. 6d.

These graphic tables are embraced in twenty-eight plates, each measuring 10x10 inches, and divided into half-inch and tenth-inch squares.

The plates are very carefully executed and they cover the conversion of units of lengths and velocities, of areas, of volumes, of weights, masses and forces, of stresses (pressures per unit of area), of densities, of energy and work, of power and of temperatures.

As pointed out by the author, the graphic tables have, over numerical tables in general, the important advantages of continuity, of reciprocity, and of reducing the labor required and the liability to gross error.

The tables are largely, but not solely, devoted to the conversion of metric into English measurements, and vice versa.

Society Proceedings.

INSTITUTION OF CIVIL ENGINEERS. Minutes of Proceedings of the ——. Vol. CXIX. London, 1895.

Among the large number of valuable papers here presented we may note especially, as of interest to our readers, "The Removal of the Iron Gates of the River Danube," by O. Guttmann; "Cost of Dredging in the Lower Danube," by C. H. L. Kuhl; "The Concrete Bridge at Munderkingen," by K. Leibbrand; "The Filtration of the Muggel Lake Water Supply at Berlin," by H. Gill, late Chief Engineer of the Berlin Waterworks; "The Rajkol Waterworks, Bombay," by R. B. Booth; "The Rainfall discharged from Catchment-Areas," by W. K. Stent; and "Windmills for Raising Water," by J. A. Grif-fiths.

The death roll includes the famous names of Helmholtz, de Lesseps and Faija.

Professor D. C. Jackson's paper on the Corrosion of Iron Pipes by Electrolysis, and Mr. S. Whinery's paper on Asphalt Pavements, both from the September number of our Journal, are abstracted at considerable length.

AMERICAN SOCIETY OF CIVIL ENGINEERS. Transactions of the —. Vol. XXXIII. No. 1. January, 1895.

This number is devoted to Mr. J. A. L. Waddell's elaborate and illustrated description of his Halstead street liftbridge in Chicago, and to the discussion thereupon, in which Messrs. Lindenthal, Buck, G. H. Thompson, F. W. Skinner, Charles E. Emery, J. S. Deans, Foster Crowell, Samuel T. Wagner, and others, take part.

A notable improvement has been effected by the use of the wax process for reproducing some (unfortunately, not all) of the illustrations, and the external appearance of the transactions has been vastly improved by the omission of the table of contents from the cover page.

NEW ENGLAND WATER WORKS ASSOCIATION. Journal of the —. Vol. IX, No. 3. March, 1895. Quarterly, \$2.00 per year; 75 cents per number.

Of the four papers presented in this number, that by Mr. E. D. Leavitt, describing "A few Examples of High-Grade Pumping Engines," was read June 15, 1894, and the other three at the adjourned quarterly meeting January 9, 1895. The latter are: "Eternal Vigilance the Price of Good Water," by G. F. Chace, superintendent, Taunton, Mass.; "The Capacity of Steam Fire Engines, Hydrants and Hose," by Dexter Brackett, assistant engineer, Boston; and "A Method of Connecting Lead Services," by W. F. Codd, superintendent, Nantucket, Mass.

An important matter of record is the resignation of Secretary R. C. P. Coggeshall, who has served the association, in various official capacities, ever since its organization in June, 1882, and to whose efforts its success is very largely due.

The communication in which the Association of Engineering Societies invited the co-operation of the New England Association is printed in full, as also the brief report of the Executive Committee, to the effect that it would not be advisable to accept the invitation.

TECHNOLOGY QUARTERLY. Massachusetts Institute of Technology. Vol. VII, No. 3. October, 1894.

Hon. George Duncan, of the Inst. C. E., contributes "Some Experience in Engineering Practice;" Mr. Louis Derr, "An Apparatus for Measuring Difference of Phase between Alternating Currents;" Messrs. A. A. Noyes and A. A. Clement, "The Electrolytic Reduction of Paranitrobenzoic Acid in Sulphuric Acid Solution;" Mr. George C. Whipple, "Some Operations on the Growth of Diatoms in Surface Waters;" and Professor Robert H. Richards, whose paper on "A New Prismatic Stadia," appeared in our journal for January, 1894, discusses "Close Sizing before Jigging," a title which, to the uninitiated, suggests the remark that the admirers of Sarah Bernhardt, in her lean estate, went in for "grace before meat." Upon examination, however, it transpires that the paper treats of the advisability of carefully assorting granular matters as to their sizes before passing them to the jigging machine.



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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

THE CHICAGO SANITARY DISTRICT CANAL.

III.* Description of the Work and the Methods of Construction on the Brighton Division.

BY ALEX. E. KASTL, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read February 6, 1895.†]

THE main channel on the Brighton Division ‡ extends from the intersection of Robey Street and the West Fork of the South Branch of the Chicago River, Chicago, Illinois, southwestward for a distance of 5.17 miles. The center line of the channel is approximately the center line of the right-of-way, which is bounded on the north by a line about 1,100 feet northward from and parallel to the north reserve line of the Illinois and Michigan Canal. The south boundary line is, in general, the north right-of-way line of the Santa Fé Railroad. The right-of-way of the Sanitary District is about 800 feet wide. The center line of the channel is a tangent throughout the Division. So far as known, the entire prism of the channel is in earth, mostly a hard, compact clay. The cross-

* Paper I of this series, Introductory, by Mr. Isham Randolph, appeared in the JOURNAL for March, 1895. Paper II has not yet been received.

† Manuscript received March 20, 1895.—*Secretary, Ass'n of Eng. Socs.*

‡ Since this paper was prepared, the Brighton Division has been abolished and the sections thereof, together with sections H and G, have been formed into a new division called the Corwith Division.

A. E. K.

section is 110 feet wide at the bottom, with side slopes of 2 horizontal to 1 vertical. The center line, as laid out, is intended for the center line of the channel of 600,000 cubic feet per minute capacity. The channel which is now being excavated is of 300,000 cubic feet per minute capacity. On the north, the side of the channel at grade is 18.37 feet to the right of the center line, and, on the south, 91.63 feet to the left of the center line. At Robey Street the elevation of the grade of the bottom of the channel is -24.45 feet Chicago City Datum, and it then slopes uniformly at the rate of $\frac{1}{40000}$ to the end of the Division, where the elevation of grade is -25.13 feet. The cut of the channel varies from about 30 feet at Robey Street to about 38 feet at the end of the Division.

At the east or Robey Street end of the Division, the channel, for a distance of about 280 feet, widens out northward and continues full depth to the center thread of the West Fork of the South Branch of the Chicago River. This end is called the Basin. Its axis makes an angle of $68^{\circ} 21'$, east to north, with the center line of the channel, and its bottom width is about 260 feet. This makes an ample connection with the present navigable waterways of the city.

For convenience in construction, the Division is divided into six sections called O, N, M, L, K and I. Section O extends from the center line of Robey Street, station $38+89.7$, to the south line of the right-of-way of the Chicago, Madison and Northern Railroad Company, station $109+11.7$; Section N, from station $109+11.7$ to the west line of the right-of-way of the 26th Street branch of the Atchison, Topeka and Santa Fé Railroad Company in Chicago, station $154+22.8$; Section M, from station $154+22.8$ to the west line of Crawford Avenue, station $182+81.0$; Section L, from station $182+81.0$ to the east line of the right-of-way of the Chicago and Western Indiana Belt Railroad, station $224+96.8$; Section K from station $224+96.8$ to station $268+46.0$; and Section I, from station $268+46.0$ to station $311+87.2$.

SECTIONS O AND N.

The contract for sections O and N was let May 2, 1894.

The excavation on these sections is to be done mainly by steam dipper dredges, the excavated material being loaded into dump scows, towed out into Lake Michigan and dumped there. By the terms of the contract no excavated material is to be disposed of on the right-of-way, except as required by the Chief Engineer. Such material as is not needed by the Sanitary District becomes the property of the contractor, and he disposes of it, outside of the right-of-way of the Sanitary District, as he sees fit.

Collateral Channel.—Provision is made for a collateral channel from

the West Fork to the main channel. This channel is to be excavated to a depth of 12 feet below Chicago City Datum, 60 feet wide on the bottom with side slopes of $1\frac{1}{2}$ to 1. At present this channel is located only from the West Fork to the north right-of-way line of the Chicago, Madison and Northern Railroad Company, its center line being about 755 feet east of and parallel to the center line of Kedzie Avenue. Up to January 1, 1895, only about 8,000 cubic yards of material had been excavated, and this by dry methods. The total amount of material to be excavated in this collateral channel is approximately 132,000 cubic yards. The collateral channel work is included in the contract for section O. On account of insufficient depth of water in the West Fork, west of Western Avenue, the dredging plant has not

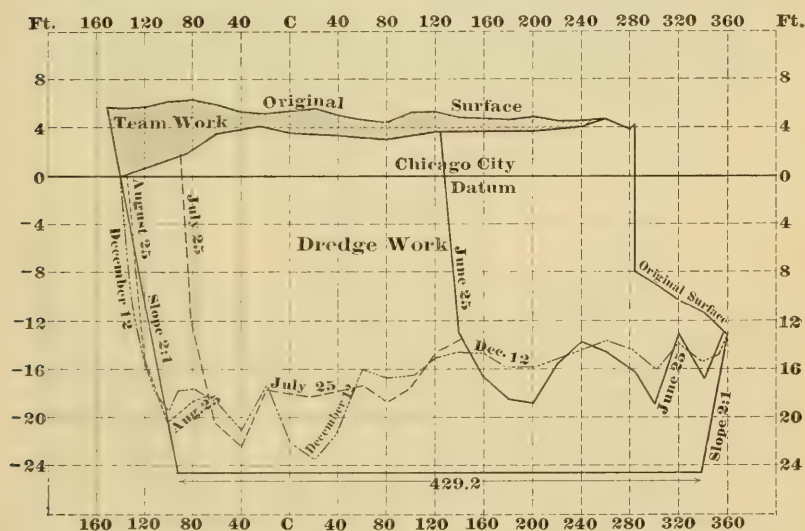


FIG. 1.—CROSS-SECTION AT STATION 40 + 50, SHOWING PROGRESS OF WORK IN THE BASIN.

yet been used on this work. However, it is expected that in the course of a few months the West Fork navigation will be improved, either by the City of Chicago or by the contractor, and then a dredging plant will be put on this part of the work. While the main use of the collateral channel during construction will be by the dredging plant, its main purpose is to provide, in the future, a navigable connection between the main channel and the West Fork. This feature has not yet been fully developed, and no further reference will be made to it, save to state that it was not projected solely to give the contractor access to the main channel work on the west end of section O and on section N.

Section O.—On section O the total amount of material to be excavated is 1,504,736 cubic yards. On January 1, 1895, about 517,000 cubic yards had been excavated. Of this amount 108,200 cubic yards have been excavated by dry methods and 408,800 cubic yards by steam dipper dredges. In the dry methods used the material is loosened with plows and removed with wheel scrapers, dump-cars drawn by horses, and railroad cars. The steam dipper dredges are of the ordinary type as seen in and about Chicago. Almost all the dredging plant has been used in this vicinity for a number of years. There is nothing particularly

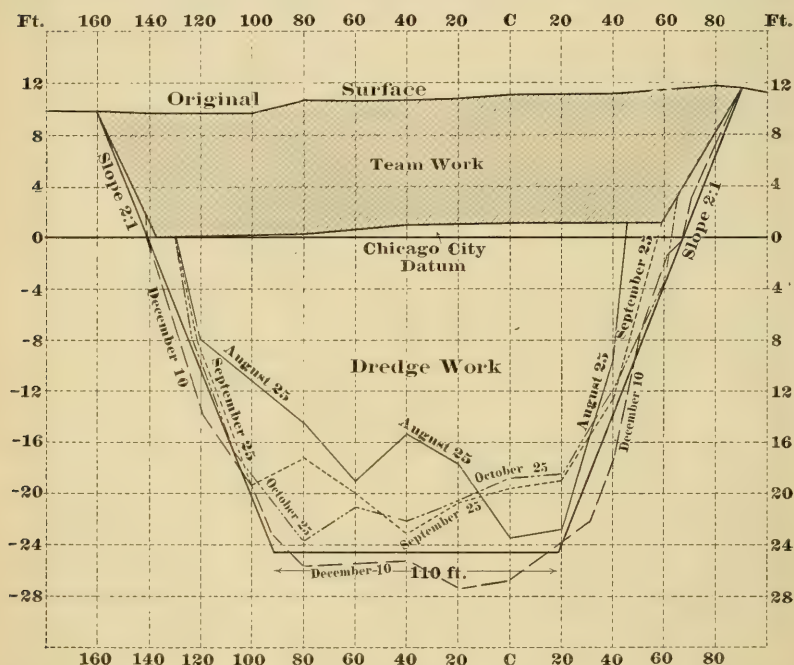


FIG. 2.—CROSS-SECTION AT STATION 52, SHOWING PROGRESS OF WORK IN THE MAIN CHANNEL.

novel in this method of doing the work. Up to the present time the dredging work has been confined entirely to that part of the channel between the centre line of Robey Street and the east line of Western Avenue Boulevard, a distance of a half mile. In this stretch the total amount of material to be excavated is 538,573 cubic yards. Of this amount all except about 40,000 cubic yards had been excavated on January 1, 1895.

The largest number of dredges employed at any one time was five,



FIG. 3.—View of the main channel looking westward from station 44, south bank, showing, on the left, portion of cut excavated by dry methods, and on the right, portion excavated by dredges. June 21, 1894.



FIG. 4.—View showing dredging plant at work ; looking eastward from station 50. Dredge No. 9 is in the foreground. July 7, 1894.



FIG. 5.—View looking eastward, up the main channel from Western Avenue Boulevard. This part of the channel is almost finished, and the dredges are engaged in finishing side slopes. October 17, 1894.

but four were worked steadily all the season, which extended from May 15th to December 27th, 1894. The number of dump scows employed varied, as many as seventeen different ones being used on some days.

The following is a description of dredge No. 6, which is considered the best adapted for handling the material found :

Length over all	130 feet.
Width over all	38 "
Length of hull	90 "
Width of hull	32 "
Depth of hull	9 "
Draught	4½ "
Length of dipper-arm, wooden part	48 "
Length of dipper-arm, including dipper	58 "
Capacity of dipper, 2½ cubic yards.	
Hoisting chains, 1½ inches.	
Two high pressure double engines :	
Cylinders of hoisting engine, 2—13'' x 16''.	
Cylinders of swinging engine, 2—7'' x 16''.	
Diameter of hoisting drum, 30 inches.	
Boiler (locomotive) 6 feet by 14 feet.	
Coal capacity, 60 tons.	
Coal burned in 10 hours, 2½ tons.	
Dredging depth, 27 feet.	
Electric lights for night work.	

The following is a description of dredge No. 9, which has the best record for average output per shift of ten hours :

Length over all	130 feet.
Width over all	38 "
Length of hull	90 "
Width of hull	32 "
Depth of hull	9 "
Draught	4½ "
Length of dipper-arm, wooden part.	38 "
Length of dipper-arm, including dipper	48 "
Capacity of dipper, 3½ cubic yards.	
One-inch wire hoisting cables are used instead of chains.	
Two high pressure double engines :	
Cylinders of hoisting engine, 2—15'' x 18''.	
Cylinders of swinging engine, 2—8'' x 12''.	
Diameter of hoisting drum, 30 inches.	
Boiler (locomotive), 4 feet by 12 feet.	
Coal capacity, 40 tons.	
Coal burned in 10 hours, 3½ tons.	
Dredging depth, 27 feet.	
Electric lights for night work.	
This is a boom dredge, the boom being suspended from shears. All the other dredges are crane dredges.	

The dimensions of the other dredges do not differ very widely from the above.

The following is a description of the best type of dump scow, built of steel:

Length, 110 feet.

Width, 28 feet.

Depth of hold, 10 feet.

Draught { empty, $2\frac{1}{2}$ feet.
 { loaded, 10 feet.

Capacity, 400 cubic yards, scow measurement.

The other dump scows are built of wood and vary as follows:

In length, from 96 feet to 115 feet.

In width, from 24 feet to 32 feet.

In depth of hold, from 8 feet to 10 feet.

In draught { empty, from 2 feet to 4 feet.
 { loaded, from 8 feet to 10 feet.

In capacity, from 230 cubic yards to 420 cubic yards.

Capacity of Plant.—From May 15th to December 11th the number of ten-hour shifts during which work was done was 661, and the number of scows loaded was 2,173. The total amount of material excavated and dumped into Lake Michigan was 400,262 cubic yards. The average output per ten-hour shift per dredge was 606 cubic yards, and the average load per scow was 184 cubic yards.

The largest average output per ten-hour shift per dredge during any month was 870 cubic yards, in July, and the least was 330 cubic yards, in November and December. During the latter months the dredges were mostly engaged in finishing the bottom and side slopes of the channel. The largest average scow load was 230 cubic yards, in August, and the least was 140 cubic yards, in November and December.

In considering the above data it is well to call attention to the fact that during all the season the dredges were worked at close quarters, and, therefore, could not be worked to the best advantage. This was due to the lack of right-of-way, the dredges not being able to proceed west of Western Avenue Boulevard. Part of the time it became necessary for one dredge to cut a channel ahead, casting the material on each side, in order to make room for the other dredges. Thus some of the material was handled twice. This would have been avoided had there been more ground to work over.

The following shows the largest day's work, done by each dredge, which came under our observation:

Dredge No. 3 loaded 8 scows in 10 hours, or about 1,400 cubic yards.

Dredge No. 6 loaded 5 scows in 10 hours, or about 900 cubic yards.

Dredge No. 9 loaded 10 scows in 10 hours, or about 1,800 cubic yards.

Dredge No. 13 loaded 7 scows in 10 hours or about 1,250 cubic yards.

The following shows the largest week's work done by each dredge :

Dredge No. 3 loaded 36 scows in 6 ten-hour shifts, or about 6,600 cubic yards, being an average output per 10 hours of 1,100 cubic yards. July 9th to 14th.

Dredge No. 6 loaded 40 scows in 12 ten-hour shifts—night and day work—or about 9,200 cubic yards, being an average output per 10 hours of 770 cubic yards. Time was lost waiting for scows. August 13th to 18th.

Dredge No. 9 loaded 48 scows in 6 ten-hour shifts, or about 9,200 cubic yards, being an average output per 10 hours of 1,530 cubic yards. June 19th to 25th.

Dredge No. 13 loaded 28 scows in 6 ten-hour shifts, or about 5,350 cubic yards, being an average output per 10 hours of 890 cubic yards. June 11th to 16th.

DESCRIPTION OF FIGURES.

FIG. 1.—Cross-section at station 40 + 50, showing progress of work in the basin.

FIG. 2.—Cross-section at station 52, showing progress of work in the main channel.

FIG. 3.—View of the main channel looking westward from station 44, south bank, showing, on the left, portion of cut excavated by dry methods, and on the right, portion excavated by dredges. June 21, 1894.

FIG. 4.—View showing dredging plant at work; looking eastward from station 50. Dredge No. 9 is in the foreground. July 7, 1894.

FIG. 5.—View looking eastward, up the main channel from Western Avenue Boulevard. This part of the channel is almost finished, and the dredges are engaged in finishing side slopes. October 17, 1894.

Section N.—On Section N the total amount of material to be excavated is 1,105,443 cubic yards. On December 20, 1894, about 71,300 cubic yards had been excavated, leaving 1,034,143 cubic yards to be excavated. All this work was done by dry methods. Some of the excavated material was used in building a levee north of the main channel and in filling up clay holes. The balance was loaded into wagons and railroad cars, and used for grading purposes in various parts of the city. The railroad cars were loaded from temporary double-ended timber inclines built across the railroad track, and high enough to allow the cars to pass underneath. The material was taken up by wheel-scrapers, hauled up to top platform of incline and dumped through trap-doors into cars underneath, the empty scrapers passing down the other end of the incline.

The dredging plant could not get access to this section for reasons already referred to under the head of "Collateral Channel." This section is entirely surrounded by railroad lines, and up to the present time the right-of-way matters in connection therewith have not been fully adjusted.

The work on both sections, O and N, is being done by firms comprising the Illinois Dredging Company and Hayes Brothers.

SECTIONS M AND L.

The contract for sections M and L was let to the Heidenreich Company on December 27, 1893.

These sections extend from the west right-of-way line of the Santa Fé Railroad to the east right-of-way line of the Belt Railroad, about $1\frac{1}{2}$ miles. They are not crossed by any railroad lines nor by any public highways. The original surface was almost a perfectly flat prairie, the west end of Section L, being about one foot higher than the east end of Section M. This topographical feature enabled the contractors to use, under the most favorable conditions, the plant to be described later on.

The sections are worked together; the plant as designed, passing back and forth over both sections.

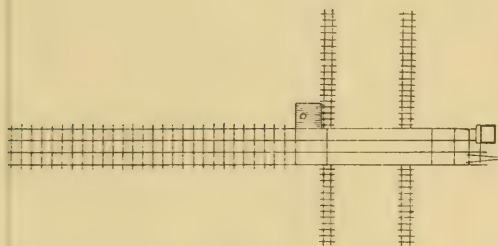
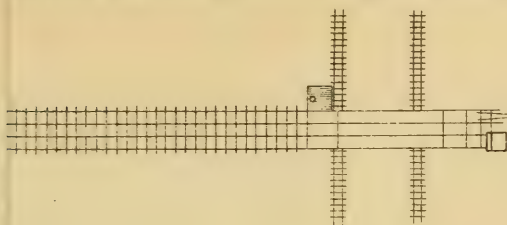
The total amount of material to be excavated is 1,811,731 cubic yards (Section M, 717,650 and Section L, 1,094,081). On December 24, 1894, about 801,870 cubic yards (Section M, 343,804 and Section L, 458,066) had been excavated, leaving 1,009,861 cubic yards (Section M, 373,846 and Section L, 636,015) to be excavated.

Of the amount thus far excavated about 178,387 cubic yards (Section M, 80,178, and Section L, 98,209) were taken out with wheel-scrapers, dump-cars and New Era graders, and the balance, 623,483 cubic yards (Section M, 263,626, and Section L, 359,857), was taken out with steam shovels in connection with inclined conveyors.

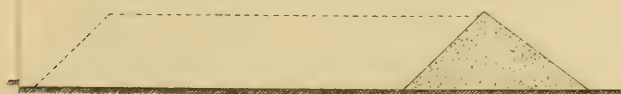
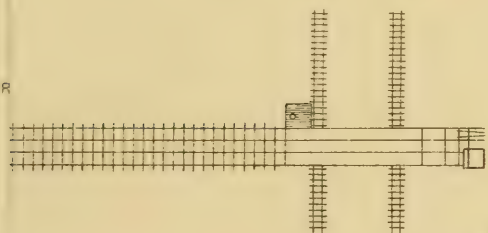
The team-work was undertaken more to keep up the contract requirements as to monthly progress than for any other reason. As soon as the excavating plant was fairly installed, the team-work was stopped.

Excavating Plant: Steam Shovels with Inclined Conveyors.—Four steam shovels are now in use. Each shovel travels on a path parallel to the center line, making a longitudinal cut. It loads the material into two cars, one at a time, and these are drawn by cable-hoisting machinery up an incline and automatically dumped from its apex. The incline moves alongside the channel at the same rate as the steam shovel, and the excavated material is dumped in a ridge parallel to the channel. When the plant reaches the end of the work, the steam shovel is turned around and the incline is moved toward the channel. Then another cut is made in the reverse direction. When two plants meet, the steam shovels pass each other and exchange inclines. The height of the finished spoil-bank will be about 30 feet. An 80-foot berm is left on each side of the channel.

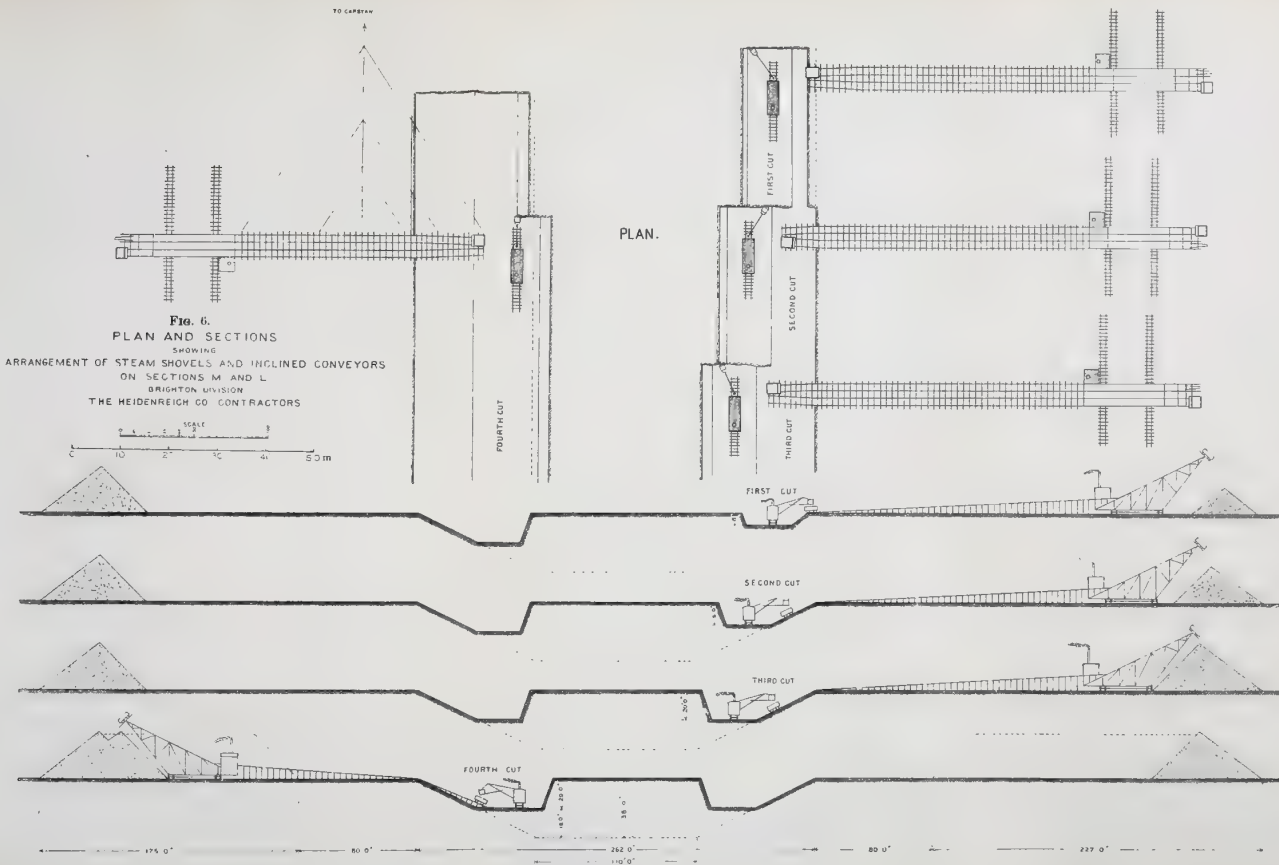
RIGHTON DIVISION, CHICAGO DRAINAGE CANAL.



ARR



227' 0"



Description of Inclined Conveyor.—The inclined conveyor proper is about 80 feet long over all; its base is about 46 feet long; its height is about 34 feet, and its width 16 feet. The upper chords, on which rests the dump-car-track system, are about 80 feet long. The apex of the incline overhangs about 26 feet, and the end of the car tippie about 8 feet farther. The side elevation looks like an obtuse-angled isosceles triangle resting on one of the equal sides, the obtuse angle being about 130° .

The incline is mounted on two eight-wheel trucks which travel on two temporary railroad tracks of 3 feet gauge and 32 feet between centers. These railroad tracks are parallel to the channel. The truck nearest the channel side is lengthened out sufficiently to carry the

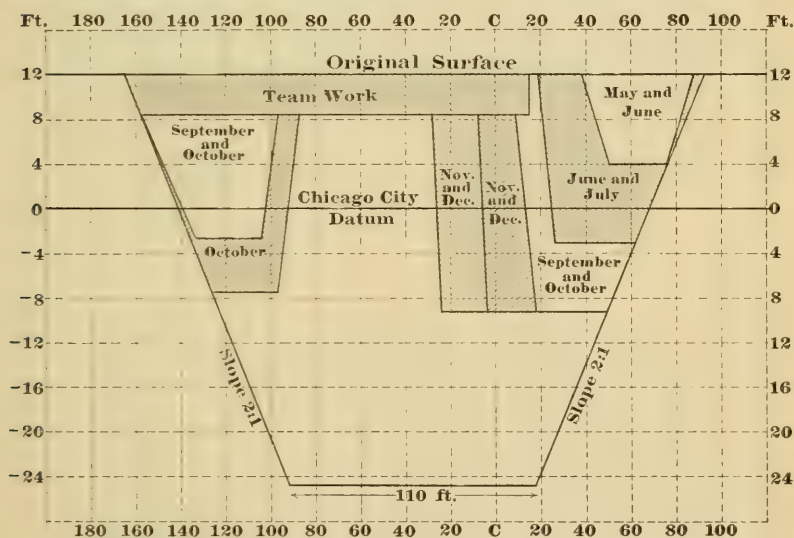


FIG. 7.—TYPICAL CROSS-SECTION SHOWING PROGRESS OF WORK TO DECEMBER 31, 1894. SECTION M.

boiler-room, which is adjacent to the incline. Part of the space in the interior of the incline nearest the channel is enclosed and contains the cable-hoisting machinery.

The approach from the channel side is made on a temporary timber-trestle. This trestle connects with the incline at a point about 10 feet above the ground, and descends uniformly to the edge of the slope. It then breaks grade and continues down the sloping sides to the steam shovel. The base of each bent of the trestle is a $6'' \times 6''$ timber, rounded upward at each end so as to serve as a runner.

The incline is moved ahead by means of a shaft geared to the car-

wheels and hoisting-engine; or, in some cases, by means of blocks and tackle, power being furnished by the hoisting-engine. The trestle approach is moved ahead with the incline by a system of light wire cables running to a capstan turned by horse-power. To prevent the approach from settling unevenly it is run across lines of planking laid at intervals. The bottoms of the runners are greased to reduce the friction.

The incline and its approach carry a standard gauge double track, 10 feet between centers. Two cars, each 9 feet long, 8 feet wide and 2 feet deep, are used. The front, or upper, end of each car is open. The cars are rated at 5 cubic yards.

The hoisting engine is a Mundy double-drum engine of 75 I. H. P.

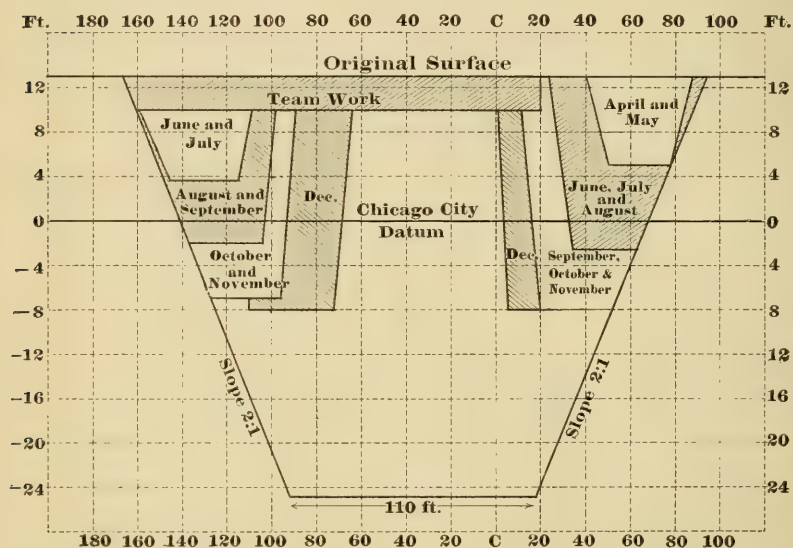


FIG. 8.—TYPICAL CROSS-SECTION SHOWING PROGRESS OF WORK TO DECEMBER 31, 1894. SECTION L.

The hoisting drums are 48 inches in diameter; $\frac{3}{4}$ or $\frac{7}{8}$ -inch wire hoisting cables are used. Each cable passes from its drum, underneath the incline, to a pulley at the end of the tippie, and then down the track to car.

Method of Working.—The method of working is as follows: One of the cars is put in position so that the steam shovel can load it. As soon as it is loaded, it is drawn up the trestle approach and the incline. On reaching the apex of the incline, where a short section of the track is pivoted on a horizontal axis, the weight of the loaded car and the tension of the cable cause the forward end of this section of track, or



FIG. 9.—View showing inclined conveyor and steam shovel, south bank of main channel at about station 190, from station 187 ; working on second cut. One car dumped and one being loaded. Section L, June 29, 1894.



FIG. 10.—View showing steam shovel at work near station 165, north bank, loading car at channel end of inclined conveyor ; empty car on top of bank ; capstan for moving trestle approach on right of steam shovel dipper ; second cut, looking northwest from station 164. Section M, June 29, 1894.

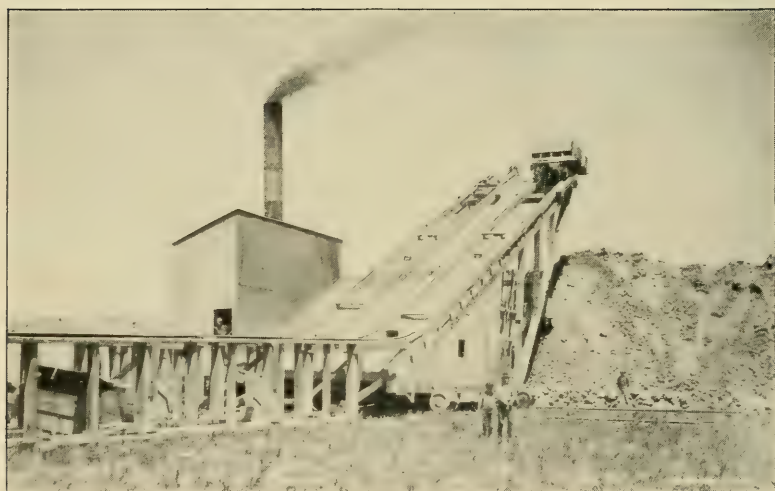


FIG. 11.—View showing incline ; car on tippie about to dump ; looking north-west. Section M, June 29, 1894.

tipple, as it is called, to drop, and the excavated material slides out of the car. As soon as the car is empty, and the tension on the cable released, the tipple is brought back into its normal position by counter-balances, and the car is again let down into the cut. In the meantime the other car has been loaded and is being hoisted. Generally, the empty car is returned to the channel side before the other car is fully loaded. Thus the cars are loaded and dumped alternately, and the shovel loses no time. When the shovel has to be moved ahead, the incline and its approach are moved ahead at the same time. The incline can be moved into a new position sooner than the steam shovel, and the latter can resume operations as soon as it is in position.

The tipple is provided with a system of hooks and catches which hold the car and prevent it from falling off when it dumps.

When a car is loaded, the engine-man is signaled to hoist it. When the car nearly reaches the top, it strikes a lever which operates an audible signal in the engine-room, thus informing the engine-man when to slow up and stop the engine. In the engine-room is also a visible signal which shows when the tipple has come back into position after dumping the car. The engine-man then releases his brake, and the car descends. The descent of the car is controlled by the signal-man at the channel side, who is able to stop the car at any point on the incline. This is done by a band-brake, on the hoisting drum, operated by the signal-man. In other words, each drum has two brakes, one of which, by a system of rods and levers, can also be operated from the channel side when the movement of the car is in plain view. By this system the engine-man is able to give his entire attention to the drum hoisting the other car, and there is less liability to accidents arising from mistakes in signaling. As a further precaution, each track is provided with a derailing switch placed on the trestle about 18 feet from the foot of the incline. In case the cable breaks while a car is near the top of the incline, the car could be thrown off the track, and much less damage done to life and property, than if it ran away into the cut. Fortunately it has not yet been necessary to use this appliance.

The excavation of the channel is made by a series of longitudinal cuts. In making the first cut the incline was placed in position just so far from the right-of-way line that when the material was dumped it would not spoil outside of the right-of-way. The first cut was about 8 feet deep and about 45 feet wide at the top, bounded on one side by the slope of the channel. The second cut was a widening and a deepening of the first cut, taking in about 25 feet of additional width and going down to 15 feet below the surface. The third cut extended out to about 80 feet from the slope stakes and to 20 feet in depth. After the third

cut the succeeding cuts were made of the same depth as the third, taking in 10 to 20 feet additional width of excavation at each cut.

The slopes are roughly dressed with the steam shovels, and then finished with plows, drag-scrapers and hand shovels.

At present there are three steam shovels and inclined conveyors on the north side of the channel and one on the south side, there being a greater spoil area on the north side. The first incline was put in operation on March 22d and the last on September 17, 1894.

Generally, after one cut is finished, the incline is moved a short distance, 5 feet or more, toward the channel, the trestle approach being shortened on the berm and lengthened in the cut.

It is proposed to complete the 20-foot cut clear across the channel and then repeat the operation for the remaining 18 feet or so of the required depth.

Working Capacity of Plant.—The largest average output of each steam shovel per ten-hour shift, during any month, was 968 cubic yards, in July, 1894, when 87,900 cubic yards were excavated in 90.8 ten-hour shifts. During that month, three plants were in operation, two working 12 hours per day all the month; and one, 12 hours per day to the 11th, and in two ten-hour shifts for the balance of the month.

The largest steam shovel output during any month was 93,700 cubic yards, in December, 1894, when the average output of each steam shovel per ten-hour shift was 808 cubic yards, there being 116 ten-hour shifts during which work was done. During that month four plants were in operation, two working each two ten-hour shifts per day and one working one ten-hour shift per day.

The smallest average output of each steam shovel per ten-hour shift was 662 cubic yards, in August, 1894.

In the above comparisons the first month, March, is not considered.

The total steam shovel output from March 22d, when the plant commenced operations, to December 24, 1894, was 623,483 cubic yards, excavated in 829.1 ten-hour shifts, making the average output of each steam shovel per ten-hour shift equal to 752 cubic yards.

DESCRIPTION OF FIGURES.

FIG. 6.—Plan and sections showing arrangement of steam shovels and inclined conveyors.

FIG. 7.—Typical cross-section showing progress of work to December 31, 1894. Section M.

FIG. 8.—Typical cross-section showing progress of work to December 31, 1894. Section L.

FIG. 9.—View showing inclined conveyor and steam shovel, south bank of

main channel at about station 190, from station 187; working on second cut. One car dumped and one being loaded. Section L, June 29, 1894.

FIG. 10.—View showing steam shovel at work near station 165, north bank, loading car at channel end of inclined conveyor; empty car on top of bank; capstan for moving trestle approach on right of steam shovel dipper; second cut, looking northwest from station 164. Section M, June 29, 1894.

FIG. 11.—View showing incline; car on tippie about to dump; looking northwest. Section M, June 29, 1894.

SECTIONS K AND I.

The contract for Sections K and I was let to Christie & Lowe on December 27, 1893.

These sections extend from the east right-of-way line of the Western Indiana Belt Railroad south-westward for a distance of 8,690 feet. They are not crossed by any public highways and only by one double-track railroad line, which, however, is at the extreme east end of the work. The original surface was about the same as on Sections M and L, but slightly more rolling. The conditions were favorable for the use of the plant adopted by the contractors.

The sections are worked as one. The work was started near the east end of Section I and prosecuted in both directions.

The total amount of material to be excavated is 2,279,402 cubic yards (Section K, 1,147,753, and Section I, 1,131,649). On December 26, 1894, about 1,095,029 cubic yards (Section K, 414,618, and Section I, 680,411) had been excavated, leaving 1,184,373 cubic yards (Section K, 733,135 and Section I, 451,238,) to be excavated.

Of the amount thus far excavated, about 471,948 cubic yards (Section K, 263,170 and Section I, 208,778) were taken out with wheel-scrapers and New Era graders, and the balance, 623,081 cubic yards (Section K, 151,448 and Section I, 471,633) was taken out with steam shovels in connection with bridge conveyors.

Wheel-scraper and Grader Work.—On account of delays in securing the necessary material and machinery for installing the bridge conveyors, and in order to fulfill the contract requirements as to monthly progress while the excavating plant was being installed, the contractors put on a force of men and teams, using wheel-scrapers, New Era graders and wagons. By these means, a layer, 5 feet to 7 feet in depth, was removed all over the sections.

On Section K about 68,300 cubic yards were moved with wheel-scrapers. Work was done on 62 days, the daily average force being 59.6 men, 36.8 teams, 23.9 wheel scrapers, and 2.0 plows. The average output of each scraper per day worked was 46.1 cubic yards. Also, on Section K, about 194,900 cubic yards were moved with New Era graders

and wagons. Work was done on 123 days, the daily average force being 50.4 men, 41.9 teams, 3.1 New Era graders and 22.3 wagons. The average output of each grader, per day worked, was 508 cubic yards, and, for each wagon, 7.1 cubic yards. The spoil area on the north was between lines 80 and 290 feet from the edge of the channel, and on the south between lines 80 and 260 feet from the edge of the channel, the average haul being probably about 500 feet.

Excavating Plant: Steam Shovels with Bridge Conveyors.—The excavating plant now consists of four steam shovels, operated in connection with four bridge conveyors. The first plant was put in operation on March 29th and the fourth on October 5, 1894.

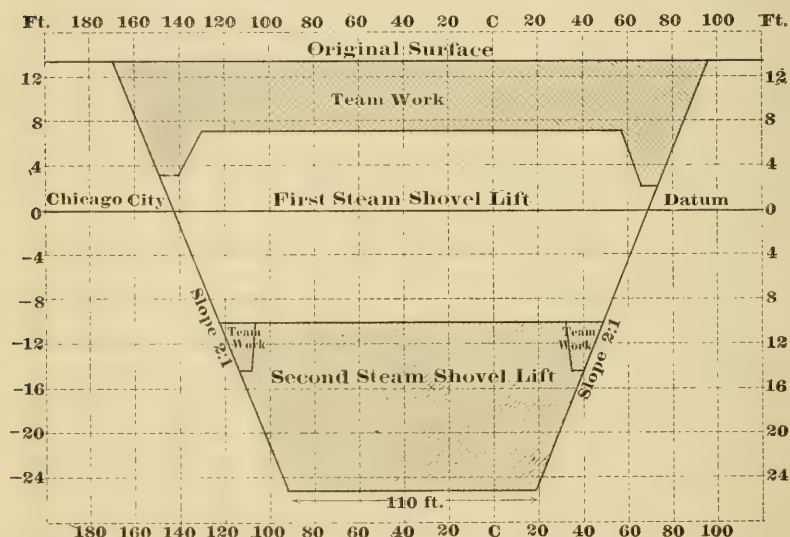


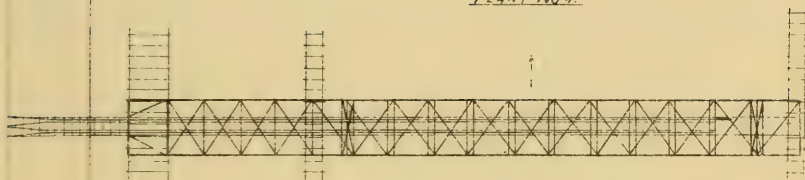
FIG. 13.—TYPICAL CROSS-SECTION SHOWING METHOD OF WORKING SECTIONS K AND I.

The excavation of the channel was to be made in two cuts of about 22 feet and 16 feet in depth, respectively. However, on account of the work done with wheel-scrapers and graders, the first cut is now reduced to about 16 feet in depth for the steam shovels.

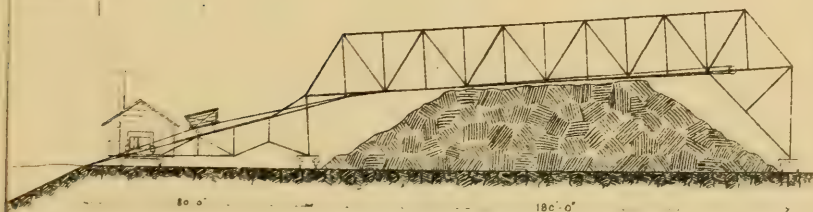
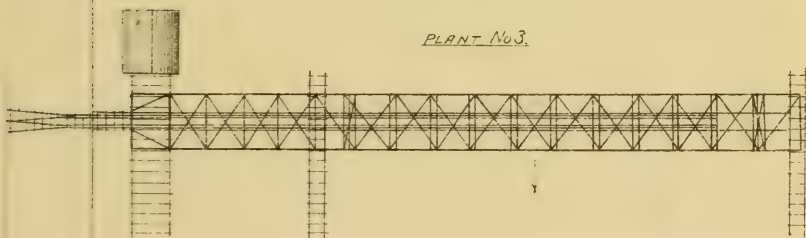
The excavation of each cut is made by two steam shovels, and the excavated material is removed to the spoil bank by the conveying systems, of which one works in connection with each steam shovel. The shovels work in opposite directions, one in each cut advancing eastward and one in each cut advancing westward. Each cut is finished from slope to slope as the work progresses. At the slopes, the work of the steam shovels is supplemented by manual labor, a small force of men

E. KASTL.—BRIGHTON DIVISION, CHICAGO DRAINAGE CANAL.

PLANT No 4.



PLANT No 3.



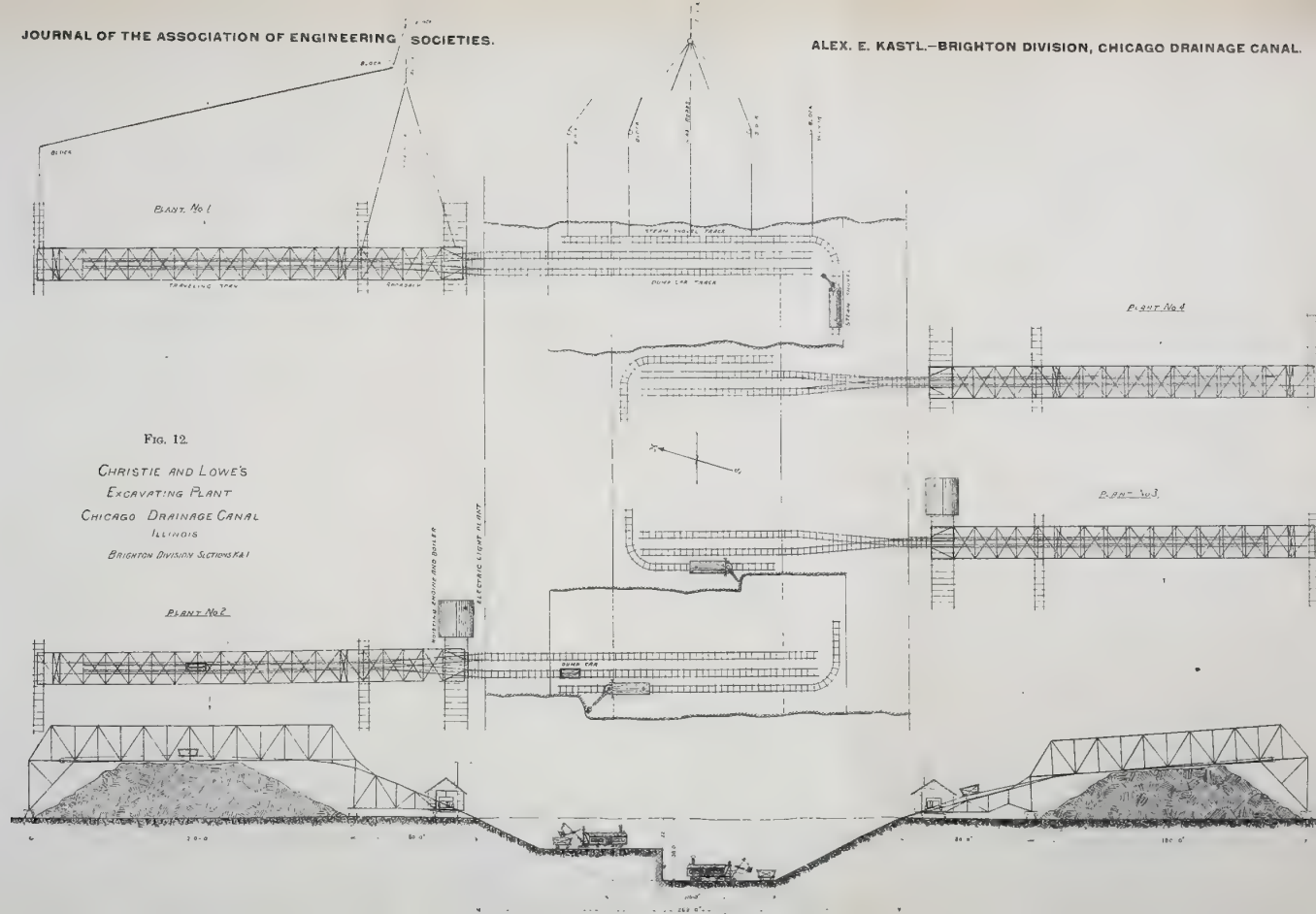


FIG. 12.

CHRISTIE AND LOWE'S
EXCAVATING PLANT
CHICAGO DRAINAGE CANAL
ILLINOIS
BRIGHTON DIVISION SECTIONS K&L

trimming the slopes and shoveling down such material as cannot be reached by the steam shovel. In order to reduce the manual labor on the slopes, a triangular cut, having the slope for one side, is made ahead of the steam shovels on each side with plows and wheel-scrapers, the material being wasted toward the center. The lower cut is finished to grade, the steam shovel wastage being shoveled by hand into the dump cars of the bridge conveyors.

The two conveyors for the upper cut are on the north side of the channel, where the spoil area is greater, and the two conveyors for the lower cut are on the south side of the channel.

Each conveyor consists of a riveted steel truss bridge, spanning the spoil area, with an inclined steel trestle approach between it and the edge of the channel. The bridge is supported by tower piers mounted on trucks, which travel on tracks parallel to the channel. The pier farthest away from the channel travels on a single track. The pier next to the channel is a part of the inclined trestle approach, which travels on two tracks of different gauges. The track next to the channel is of wider gauge, and the truck which travels on this track is made long enough to carry the power-house containing the boiler and the hoisting and electric lighting machinery. The bridge and incline carry a double track, which is continued down the slope and across the bottom of the cut. The tracks on the bridge overlap, a single-track structure being all that was required. This arrangement of the tracks obviates the use of switches.

Each bridge on the north side is of 210-foot span, and each one on the south side of 180-foot span. The bottom chords of the trusses are about 35 feet above the surface of the ground. The inclines are each 80 feet long, and the width of the berm is 80 feet also. The floor of the 210-foot bridge is level, while that of the 180-foot bridge slopes toward the channel at the rate of 1 in 20.

The steam shovel travels on a track laid across the bottom of the cut, next to the working face and parallel to the conveyor's pit tracks. The latter are near enough to the steam shovel's track to permit the steam shovel to load cars placed on the conveyor's tracks. In working, the steam shovel makes a cut across the channel, from slope to slope. At the side of the channel farthest from the conveyor the steam shovel's track curves (radius of curve, 30 ft.) backward and continues a short distance (25 feet) along the foot of the slope. The part of the track back of the curve can be separated from the main track. When it is desired to move the main track ahead for another transverse cut, the steam shovel is run back onto the short track.

The cars used with each conveyor are two in number, 8 feet long, 8 feet wide on top and 6 feet 7 inches at the bottom, and 4 feet 8½ inches

deep, with 9-inch sideboards. They are side-dumping, and they hold about 8 cubic yards each. While being dumped, the body of the car remains stationary, only the sides, which are hinged at the top, being moved. The cross-section of the material space of the car is shaped somewhat like the letter W, the center lines representing the floor and the side lines the doors. When the doors are released the material slides out. The apex of the floor is somewhat lower than the top edges of the car box (4 inches and 13 inches at ends and sides, respectively). The cars are alternately drawn on top of the bridge by cable hoisting machinery. The hoisting engine is of 100 H.P. The wire hoisting cable is one inch in diameter. It passes from the drum of the hoisting engine to a pulley underneath the incline, then underneath the floor of the incline and bridge to near the end of the latter, where it passes over a pulley and then back along the top of the floor to the car. Of course there are intermediate pulleys and rollers, which carry the cable in a proper manner. On the long spans another cable, $\frac{3}{4}$ inch in diameter, is used to pull the car back into the cut, while on the short spans the tail cable is dispensed with and the car descends by gravity as soon as the tension on the hoisting cable is released. Only one set of cables is used with each conveyor, the head and tail cables being coupled first to one car and then to the other.

Method of Working.—The method of working is as follows: One of the cars is put in position and is loaded by the steam shovel. Then the cables are attached and it is drawn up onto the bridge, where an attendant signals the engine-man when to stop. When the car is stopped at the proper place the attendant unlatches the levers holding the side doors in place, and the material slides out and falls through the bridge floor spaces onto the spoil area. As soon as the car is emptied, the side doors are automatically closed, and the attendant signals for the return of the car to the pit, where the car is again placed in position and the cables uncoupled and attached to the other car, which, in the meantime, has been loaded. Thus the cars are loaded and dumped alternately. When the steam shovel finishes its cut across the channel, it is moved back around the curve to the short piece of track, which is then disconnected from the main track. Then the whole system—bridge, incline and pit tracks—is moved ahead 15 to 20 feet. The movement is made by systems of cables which are attached to the bridge and pit tracks and which run to capstans and winches operated by animal power. When the tracks are in a new position, a section of track is placed in the space made in the steam shovel track, and the steam shovel is moved ahead to work on its new cut. It takes from 45 minutes to $1\frac{1}{2}$ hours to move.



FIG. 14.—General view looking west, down the channel from left bank, showing in the foreground the upper cut as left after the team work. On the right are the two bridge conveyors for the upper cut, and on the left the two bridge conveyors for the lower cut. Triangular cut on the left and capstans on the right.



FIG. 15.—View looking west, down the channel, showing part of completed channel and lower and upper cuts, with steam shovels and conveyors working at the same. The pump-house is on the left over sump, to which ditches lead for draining the excavations of rain water. Completed channel, 110 feet wide at bottom, slopes 2 to 1, and 38 feet deep.



FIG. 16.—View looking north. End view of steam shovel, incline and 210-foot bridge at east end of upper cut. The steam shovel is at the end of its cut, which is about finished.

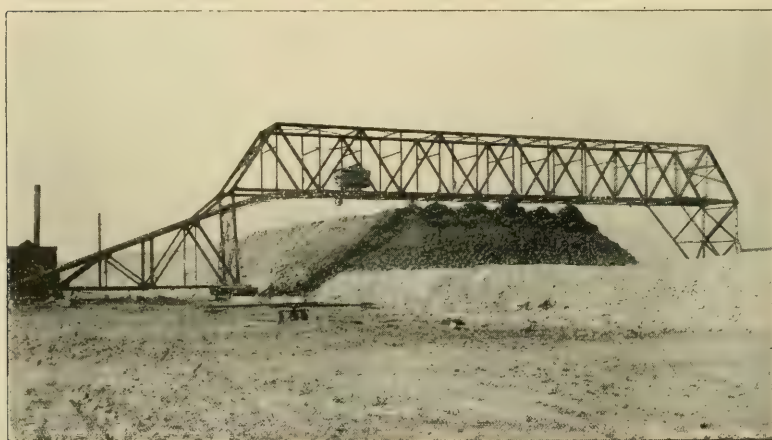


FIG. 17.—Side view of east 210-foot bridge and incline of first or upper cut; loaded car on bridge; note head and tail cables; capstan in the foreground.

The two plants on the lower cut leave a finished channel behind them.

On December 26th, about 2,100 feet of the channel were practically completed.

Working Capacity of Plant.—The largest average output of each steam shovel, per ten-hour shift, during any month, was 695 cubic yards, in December, 1894, when 109,805 cubic yards were excavated in 158 ten-hour shifts. During that month all four plants were in operation, working day and night ten-hour shifts during the first two-thirds of the month; during the balance of the month, two of the plants worked only day ten-hour shifts. A still larger average output is indicated during the month of June, when it was about 730 cubic yards per ten-hour shift, the total steam shovel output being estimated at about 38,000 cubic yards. During that month one plant was in operation, working in two ten-hour shifts per day. However, it must be said that on account of being involved with some team work, the June steam shovel output is not accurately known, the above being the most conservative estimate.

The largest steam shovel output during any month was 123,147 cubic yards, in November, 1894, when the average output of each steam shovel per ten-hour shift was 582 cubic yards, there being 211½ ten-hour shifts, during which work was done. During that month all four plants were in operation, each working in two ten-hour shifts per day of twenty-four hours.

The smallest average output of each steam shovel per ten-hour shift was 515 cubic yards and 570 cubic yards, in May and September, 1894, respectively.

In the foregoing comparisons the first two months, March and April, are not considered.

The total steam shovel output from March 29, when the plant commenced operations, to December 26, 1894, was 623,000 cubic yards, excavated in 1025 ten-hour shifts, making the average output of each steam shovel, per ten-hour shift, equal to 608 cubic yards.

DESCRIPTION OF FIGURES.

FIG. 12.—Plan and sections showing arrangement of steam shovels and bridge conveyors.

FIG. 13.—Typical cross-section showing method of working Sections K and I.

FIG. 14.—General view looking west, down the channel from left bank, showing in the foreground the upper cut as left after the team work. On the right are the two bridge conveyors for the upper cut, and on the left the two bridge conveyors for the lower cut. Triangular cut on the left and capstans on the right.

FIG. 15.—View looking west, down the channel, showing part of completed

channel and lower and upper cuts, with steam shovels and conveyors working at the same. The pump-house is on the left over sump, to which ditches lead for draining the excavations of rain water. Completed channel, 110 feet wide at bottom, slopes 2 to 1, and 38 feet deep.

FIG. 16.—View looking north. End view of steam shovel, incline and 210-foot bridge at east end of upper cut. The steam shovel is at the end of its cut, which is about finished.

FIG. 17.—Side view of east 210-foot bridge and incline of first or upper cut; loaded car on bridge; note head and tail cables; capstan in the foreground.

RAILWAY LOCATION AND CONSTRUCTION AS PRACTISED IN THE WESTERN STATES.

BY W. B. LAWSON, MEMBER OF THE DENVER SOCIETY OF CIVIL ENGINEERS.

[Read September 5, 1894.*]

THE primary intent of this paper is to place before the reader an outline sketch of the methods used in constructing our Western railways, and something of the circumstances surrounding the builders; not to give theoretical instruction, or to tell an unknown tale. The author has been for some twenty-five years in the midst of the fray, both as a pawn and as a player in the game, and the statements made are such as his experience warrants.

The lenses through which the critic views our railway systems and scans their details, can never be of sufficient power to reveal the barbed environments which circumscribed the actions of the time; nor can present analysis reveal the value, then placed upon fragments of time or upon small amounts of capital. To seize quickly the golden opportunity, and bind it with the slender means within quick grasp, lines with rich prizes at the yonder end were often cut! Uncaught fish are of little worth when the craft that floats us must be quickly handled or be wrecked. Yet a critic might declare, "A sad mistake was made right there."

MANNER OF GROWTH OF RAILWAY SYSTEMS.

No one of our great systems is the result of a carefully pre-arranged plan, but rather that of a welding together of numerous fragments, either ready made, or built as the plans developed and as seemed expedient to the management in temporary control; straight links, and crooked links, hooked together as they lay—'tis a wonder they are so good; 'tis a pity they are so bad. The rapid growth of plans, the whirl of events, and the tremendous energy displayed in wresting vast territories from wild nature, and from the other fellow, form a history of intense activity, which may be but outlined by the most masterly hand. The mainspring of all this energetic activity, was private gain, a feverish desire that the reaper should keep pace with the sower, as well as an ambition to lead in the race.

Corporations for any legitimate purpose are easily and cheaply formed, and often personal liability therein is too easily avoided. Before

* Manuscript received April 10, 1895.—*Secretary, Ass'n of Eng. Soc's.*

the era of consolidated railway interests, railroad companies, some of village and some of national repute, were formed by hundreds, the latter to acquire some Government rewards, amounting in some cases to a score of thousands of acres of land and guaranteed interest upon a certain capitalization for each mile of railway built. Others availed themselves of state, county, municipal or private aid, either voluntarily offered by the people or diligently wheedled from them. While this aid, when honestly earned, has been usually a good investment for the donors, it accounts for many errors in location, of more or less importance, and for much seemingly extravagant economy in original outlay. In after years, when a furious race for supremacy came on, companies found themselves seriously hobbled by grades and detours unwisely introduced to secure some local aid. Still, many lines, of great importance now, could not have been built for many years without such help, and the policy, with all its evils, certainly accelerated the progress of development. The railroad syndicates very promptly formed land and town companies, which controlled the location of, and the title to, all new town-sites. Strangely (?) the original settlers were wonderfully unsuccessful in selecting just the proper site for a railway station, and villages seldom dared to refuse the required bonus "in compensation for the trouble incident to a station inconveniently located." Local aids were pledged to grade and tie the road; the right of way and grade was pledged to iron and equip it. Railway stocks went with the bonds as a make-weight; the acquired land grant was appraised low, railway stocks were sometimes made legal tender for lands, and the syndicate seldom happened to take the poorest lands in theirs. Thus sowers raced, and reapers trod their heels;—small wonder there was haste.

More recently, lines have been built to sell to one or the other company, many of them in the line of legitimate progress, but others vicious blackmailing schemes that blighted prosperity and retarded progress.

The larger extensions are now usually succored by some large corporation, or by individuals therein, having sufficient influence to secure their adoption by the company in good time. This is usually done with great secrecy, shrewd strategy and many denials. Local corporations of small pretensions are organized, by which contracts, and deeds for right of way are taken, and for which locations of line are more or less perfected; local rivalries are skillfully stimulated; men of local influence are flattered by official places; communities and individuals are caressingly milked quite dry of rights of way and privileges, and sometimes monetary gifts are made, although the latter practice is becoming of ill repute. When the scheme is ripe, a new company is organized, into which all local companies are merged, from which the now useless dignitaries of local repute are excluded, and by which, inconvenient pledges

made by these dignitaries are often ignored. The child is adopted by the parent company, either openly, as one of the family, or covertly, as a poor relation on probation.

Of course our railway managers are sometimes wonderfully farsighted and keen in anticipating future exigencies, and in making all possible preparations for speedily capturing unoccupied territories in future years. Rival companies of gigantic resources hunger for the same game, when large enough to pot; and each watches the territory as does a hungry hawk the sward beneath. When the race for supremacy *does* come, mighty feats are done; each day new leagues are bound in iron bands, and Queen Silence is forever banished. To the intense excitement of such races, and to the desperation that seems to seize one or more of the rivals at witnessing the boldness and strength of the other, must be attributed many of the reckless entanglements of rival systems. It was a war between giants, and treasure was poured out with a lavishness that sorely challenged the reputation for sagacity that some of our strongest men had won before, and which arms the anti-corporation howler with powerful weapons of attack. But the sketch of conditions of growth is sufficiently amplified to furnish, to stranger and to critic, the key to many riddles.

CHIEF ENGINEER OF LOCATION.

Upon the chief engineer of location falls the burden of responsibility as to the possible economy of the line as it is developed under traffic, and yet he may not be permitted to locate it in accordance with his best judgment, for that judgment may be overruled arbitrarily by others, or by the force of circumstances, but such overruling leaves no trace of its action. To him also falls the personal supervision of the endless details of location. He either makes the original reconnoissance, or examines, at least, the best of the routes indicated by trusted assistants, and familiarizes himself with the general topography of the country and with such of its details as may affect the line chosen; as well as the resources of the country, the most promising town-sites, deposits of valuable material, the characteristics of the climate, soil, water, etc. In short, he must be authority upon all the questions which the fertile brains of the directors may concoct, and not unusually must he make a mental estimate of the cost of the road-bed, and of the time required for construction, in advance of any figures based upon measurements. It requires rare powers of quick and accurate observation, and of keen analysis, a retentive memory of locality, and sound judgment, to fill the bill. The quickly formed mental estimate of cost is often strangely near the truth; the skill to make it is a faculty highly cultivated in some, and never acquired by a dullard. He furnishes the field

engineer with general plans of all ordinary structures, with simple formulas for calculating the cost, or with memoranda of the same, as well as of the cost of grading, the maximum grades and curves permissible, the value to be placed upon distance, curvature and undulation saved; of permanent bridges eliminated, etc., etc. He inspects the line as laid, and the location and size of drainage structures, closely scans the cubical quantities calculated, fixes prices upon different portions, signs the preliminary estimates, and makes reports to directors. It is not unusual for an imperative demand to come for an estimate to be completed within two or three days, which, regularly calculated, would require as many weeks. "A special meeting of financiers must consider the scheme at an early date," or some such importunate circumstance seems always lying in wait to crowd the engineer. He must submit his best effort, upon which his reputation more or less depends, without show of hesitancy or discontent, or he incurs the odium of clogging the machinery by slow motion.

The problems incident to a scientifically adjusted location have been solved, upon the major portion of our railroads, largely by personal judgment alone, each engineer deciding for himself, by reasoning upon the particular case at hand, often with an acumen that bears the searching test afforded by unexpected volumes of traffic, and sometimes with the sole idea that a smooth light profile was the one supreme test of the ability of an engineer. The individuality of the locating engineer is traceable wherever he has worked. This applies the less, however, as the science advances, and as railway schemes are carried out with more deliberation. This fact is not surprising under the circumstances. Consider them!

Many of the most active locating engineers of former days, spent years at the front, rarely meeting a fellow craftsman or even seeing the work of other engineers; almost constantly remote from communication, and deprived of professional literature (aside from nature's volume and his own pocket note-books), with every day of his life crowded with pressing duties. A brief call upon his family, or from his wife, was the only shining light enjoyed during months of a life devoted to the stern demands of a calling arduous to the very extreme. Very eagerly have they drunk, upon opportunity, of the wisdom of others, but perforce they have been inventing methods, and gathering experience personally, striving, each to the best of his ability, to prove himself a man of superior ability in his profession. Indeed, the literature of this branch of the profession, at all applicable to practice under the conditions, has been extremely limited, until years subsequent to the growth of the greater portion of our railroad systems. Many of the conditions met and conquered by force of original good sense and judgment were never

met before, and still remain unrecorded. Many more or less arbitrary formulas, for calculating the alleged justifiable expense of eliminating a foot of distance or of undulation, or of a degree of curvature, have been used. Some of these are the result of elaborate calculations. They are useful, in comparing the values of different lines, as is a string of unknown length, in comparing unknown distances—but a railroad, located by the best formulas extant, might present many absurdities of great or small degree; for the simple reason that values of the same unit are not equal in different localities, even upon the same line or upon lines carrying the same traffic, even, possibly, within very short distances.

The following appears in the author's memoranda, as having been used by different engineers upon trunk line location:

TABLE USED IN EQUATING VALUES OF DISTANCE, CURVATURE AND UNDULATIONS ON THE X RAILWAY.

Upon ruling gradient of	Distance value, per foot.	Curvature, per degree.	Undulation, per foot.
0.4	\$ 2 60	\$10 00	\$ 35 00
0.5	2 80	10 80	39 00
0.6	3 00	11 60	43 00
0.8	3 40	13 10	47 00
1.0	3 80	14 50	51 00
1.2	4 30	16 30	59 00
1.4	4 80	18 40	67 00
1.7	5 60	21 40	75 00
2.0	6 50	24 60	91 00
3.0	9 80	37 10	107 00
4.0	14 20	54 00	123 00

Distance value to be doubled for 5 or more miles saved. Table said to be for 100 trains per day, with coal at \$12.00 per ton.

Upon Y railway.

Distance, per foot, \$9.00.

For reduction of one degree in maximum curve per section of two miles, \$2,000.00.

For reduction of curvature, per degree, \$50.00.

For reduction of maximum grade per foot per mile, on divisions of 100 miles, \$2,500.00. With maximum gradient fixed, reductions elsewhere, as above, \$600.00 per foot per mile.

Upon Z railway.

Formulas for equation of curvature, where n = total number of degrees, and where d = degree of curve.

$$30 (10 + \sqrt{n \cdot d^3}) = \text{value of entire curve, in dollars.}$$

These will serve to illustrate different approaches towards the truth.

A reduction of the maximum gradient, to compensate for curve resistance, was formerly overlooked upon many lines, as were spiral approaches to curves, until still more recently. The use of both now prevails.

As to grade reduction, practice has varied as follows:

(1) For 1° curve 0.03 ft. per 100 ft., increasing to 0.05 for a 3° curve.

(2) For grades up to 0.7 per cent., 0.06 ft. per 100 ft.; for grades from 0.7 per cent. to 1.4 per cent., 0.05 ft. per 100 ft.; for grades above 1.4 per cent., 0.04 per 100 ft.

(3) For maximum grades under 1.5 per cent., 0.05 ft. per 100 ft.

(4) For maximum grades up to 4 per cent., 0.03 ft. per 100 ft.

Nos. 3 and 4 indicate the allowance now usual for prairie and mountain lines respectively.

Surveying parties number from twelve to sixteen men, including the engineer in charge. They are usually composed of bright, energetic and ambitious youths, who work from dawn until dark, and accept their rough camp life and untoward hardships, or perilous situations, with great good humor and with unquenchable spirits.

The locating engineer must be untiring in his diligence; up first in the morning, and often working hours after all others rest, regardless of poor candle light, plaguing insects, and other ills of life. He scouts the country in advance, weighing in his mind the various assortments of difficulties to be overcome, measures with his eye and compares horizontal and vertical distances, and directs all movements of his party. To attain marked success, he must be quick and accurate in judgment, unfatiguing in exertion, a leader of his men in all situations, commanding the esteem and personal allegiance of his party, and an excellent judge of country. The skill acquired by some in the last particular is marvelous. Usually the locating engineer runs the first line from a summit down hill, supporting an imaginary grade line by eye alone, and then corrects this line in projecting the line of continuous survey. In an accustomed country, with gradients from two to four miles in length, he should rarely misjudge the cut or fill at any point more than a few feet, and many times corrections are unnecessary, save for more carefully considered alignment.

Fully as great ability is required in the rougher prairie land as in the Rocky Mountains, as the limiting elements of the line are in a corresponding ratio with the difficulties met, and the calls upon judgment in choosing between numerous variations of alignment are far greater on the prairies. In the mountains, the gradient contour must be followed

(approximately) from top to bottom by purely instrumental methods, as any slight change of the conditions, such, for example, as the minimum radius, or equation for curvature, will, within a few miles, change the length of line, and consequently the elevation of grade line, sufficiently to require an entirely different development. The process is here mechanical, although requiring an adjustment of line to inches, in lieu of feet, in the flatter countries. Much of the mountain practice seemingly indicates that the engineer's formulas and study were directed towards eliminating tangent. The minimum radius was first established by test as to the sharpest curve the locomotives on hand could crawl around, and the gradients were established by the average fall of the stream followed, providing the locomotives could move themselves, plus something, thereon: and the first cost was reduced to the lowest, regardless of curvature. This may appear anything but skillful engineering, but financiers were rare that had nerve to invest in schemes considered so hazardous, and dollars had to be expanded, not expended. Without skill in expanding dollars, treasures inconceivable would still be untouched. The cost of location per mile varies extremely with the obstructions met and with the skill of the engineer in charge; and a variation of 100 per cent. in the progress made, and attributable to difference of skill and energy alone, as between engineers, is not unusual.

In undulating, partly timbered countries, 4 miles of closely laid preliminary is considered a good average daily progress, costing some 8 or \$10 per mile. In open, flat countries, good work may be done at the rate of 1 to 1½ miles per hour. The cost of final location, including the preliminaries, upon the particular route selected, varies from about \$40.00 per mile in undulating countries, to fully \$2,000 per mile in the high mountains.

Where slopes are easy, contours are usually sketched by the hand level and pacing; in the mountains, by aid of center line profile, hand level and tape. The linked chain is pretty well superseded by the steel ribbon. Alignment work is occasionally checked by reference to the meridian, and errors of a few minutes are ignored. Levels are checked by repetition, and a variation of 0.2 foot in any one mile is often ignored, although location levels are usually much closer. Skillful instrument men are common, but extreme accuracy is too costly. The decimally divided foot, 100-foot stations, designation of curves by central angle for chord of 100 feet, the transit, the wye level, non-inverting lenses, and self-reading levelling rods, are used almost universally. Upon location, the station elevations are often taken to the nearest 0.05 foot upon a peg driven at the exact station and level with the surface.

Construction is usually entered upon suddenly, and pushed with an energy that is insatiable in its demands for *more* work and *less* time.

The engineer that has the start of a well-considered location line, before construction begins, is very fortunate. Location, construction and finishing grade stakes may all be urgently demanded of an engineer in a single day's work. Even when the chief engineer may know, for days ahead, that construction is to be crowded, he is liable to be restrained from the slightest move towards organizing his department, or from indicating in any manner a possible change in the situation until the time is ripe. Premature publicity would often be a great misfortune, and very rarely does an engineer enjoy the felicity of well-matured plans completed, and earthwork staked out, in readiness for a rush. When the time comes for action, then is the good metal in him tested. Presidents, superintendents, purchasing agents, right-of-way men, contractors, land owners, village delegations, patent-right men, newspaper men—and who not?—all heap work upon him in avalanches, or clamor for information and data regarding everything which their fertile brains can imagine may some time be wanted. Everybody, seemingly, intends to saddle him with any possible delay that may occur. Meanwhile, he must gather, it may be, scores of assistants from hither and yon, many of them strangers, size them up in a brief interview, assign them work, furnish them everything needful in plans, instructions, etc., and see that each takes hold of his portion satisfactorily. It is red hot work, but gloriously exciting, this concentration of weeks of vivid life into days! Were there not hosts of intelligent, energetic, honest men, trained to push in any gear, loyal to the company that pays them and to the chief that commands their respect, the organization and placing of a force upon some hundreds of miles in a fortnight, under such circumstances, would be well nigh impossible. The organization of the construction corps varies with circumstances and with personal ideas. A large undertaking is usually divided into portions of some 50 or 60 miles, each in charge of a resident engineer, whose charge is subdivided into divisions of a few miles, and a group of three or four men is assigned to each, under his immediate control. The chief holds the resident responsible for the proper execution of the work, and looks to him for constant information as to details, daily reports of all forces employed, monthly estimates and progress profiles, etc., as well as advice as to men and methods. In short, the resident engineer carries so much of the responsibility as his chief sees fit to intrust to him. The division engineers lay out the work, make all measurements, and work under specific orders in everything. The chief issues all plans and specifications, signs and interprets contracts, orders materials, has more or less control of right-of-way matters, makes monthly estimates of work done and materials furnished; arbitrates in complaints and disputes, numberless and annoying; makes reports upon endless matters, spurs everybody, and is supposed to see

everything, know everything, shoulder all mistakes, and please everybody.

The cost of superintendence varies almost directly with the number of details to be looked after, ranging probably between \$20 and \$50 per mile per month, including office expenses and salary of special corps in charge of important bridges, etc.

The right-of-way limits are generally defined by lines parallel with the center line and at a given distance from it. A strip 50 feet wide upon each side has become a standard width in most of the Western states, and is so recognized by the courts. It is often narrowed to exclude costly property, sometimes at great future cost. In such cases the chief engineer gives the narrowest limits practicable for present use. He also calculates the extra widths necessary on account of the nature of the work. Condemnation proceedings, under the act of eminent domain of the state, for public use, vary in the several states. In some of them, some kinds of property are not subject to condemnation. Usually, good reasons for acquiring widths above the standard are required in such proceedings, which give only an easement for railroad purposes, the title reverting to the original owner upon abandonment of the property. Titles in "fee simple" are acquired only by private purchase, are not generally taken, but are especially preferable in towns and cities, and, generally, in all cases. The government grants a strip 200 feet in width across its lands. The engineer furnishes the right-of-way department with maps showing all lines of government surveys, the numbers of townships, ranges, and sections, divided into forty (40) acre tracts, property lines, adjacent improvements, road-ways and the required right-of-way, and writes descriptions of irregularly shaped pieces required. Good practice fixes all right-of-way corners upon lines easily re-established from lines of government or city surveys, instead of at right angles to the center line opposite some station of the original survey, as is commonly done. It also acquires isolated bits of estate in the first instance; as reasonably convenient access to all property and to the highway is every man's right, regardless of cost to the railway company. No contract for a certain kind of crossing, or other unusual agreement, should be made without the consent of the engineer.

Contracts are usually let by competition between invited bidders. The amount of work, the ability of contractors, and other like circumstances, control the size of the contracts. Principal contractors are usually men of integrity, financial standing, immense energy and executive ability, and are often better practical engineers than the men in charge. They usually have in direct control sufficient teams, tools and men, to execute the more difficult portions, or those that for any reason drag behind, with an expedition that is at once an example and a warn-

ing to sub-contractors. They also have a large contingent force of sub-contractors, boarding bosses, overseers, etc., each with an outfit, small or great, and each more or less expert in special classes of work. These men habitually live in tents or shanties, constantly moving from one work to another, often hundreds of miles between, with fortunes constantly varying, but with a marvelous pluck that always has bright hopes for the next job. To their energy and pluck are largely due the many great achievements in their line. The great variety of soils, with their peculiarities under different conditions of weather and relative position, require of the successful railway builder a large fund of practical information, drawn from close and extensive observation, which cannot be acquired except by experience.

Western contractors lead the world in the use of the best appliances for the work in hand, and, as a class, deserve great honor for their achievements. Single-track, standard-gage road-beds, upon embankments, are usually from 12 to 15 feet in width, in earth excavations from 20 to 22 feet. Embankment slopes, 1 vertical upon $1\frac{1}{2}$ horizontal, are almost universally used, blindly so, for high fillings, as neither sand nor the ordinary soils will stand at this slope. Slopes of 1 in $1\frac{3}{4}$ have grassed over permanently, where adjacent slopes of 1 in $1\frac{1}{2}$ gave much trouble and expense. For cuttings, various ratios of slopes find defenders. In ordinary clays 1 in $1\frac{1}{2}$ is prevalent on new work, but they are often made steeper to save time or from mistakes as to economy, as material is generally removed from the side ditches by train in the form of mud until the top width of the cutting corresponds to that given by slopes of 1 in 2, or flatter. Material alongside a railway assumes flatter slopes than seem natural elsewhere.

The cost of earthwork varies considerably with surrounding circumstances. Grading of from about 1 to 4 feet in depth may sometimes be done for 8 cents per cubic yard. The prices to railway companies upon large contracts range from 12 to 18 cents per cubic yard for earth, 35 to 45 cents for loose rock, and 65 to 95 cents for solid rock. These are averages for the greater portion of the work done. The prices include a haul of from 200 to 500 feet, where necessary, above which 1 cent per cubic yard per 100 feet is usually paid additionally. This is usually calculated upon the whole number of cubic yards, multiplied by the distance between centers of gravity, less the free haul. Elaborate methods of calculation have not found general favor. The prismoidal formula is generally applied to calculations of earthwork by means of tables, although the cross-sections may have been carelessly taken, and deductions, on account of rounding slopes or narrow widths, may be *guessed* at the same time. More careful measurements of contents, and calculations by end areas alone, are practices which engineers graduate into by experience.

An allowance of from one-twentieth to one-tenth the height of scraper fillings is a common allowance for settlement, from one-tenth to one-eighth for wagon work, and upon wheelbarrow and grading-machine work, all one's conscience and the circumstances will permit. These allowances should be reduced under many conditions of time and weather during construction. The practice of measuring in excavation only does not prevail. The usual practice is to calculate center line quantities as per cross-sections, and the major quantity, whether in excavation or embankment, is paid for.

Classification of material is the engineer's *bête noire*, and the almost universal bone of contention between contractors and engineers. Some roads have thoroughly tried six or eight classifications in a vain attempt to eliminate disagreements, and have abandoned them for three only, viz.: earth, loose rock, solid rock. Definitions of these materials vary, but vexation of spirit is the shadow that always follows the responsibility of classification.

Wooden culverts are, of necessity, in common use, and, as usually built, are consistent with good (but not permanent) construction. Under low embankments with ordinarily good construction they are not objectionable when not too old, and, if properly cared for, they never fall down, and seldom wash out if nearly large enough. Good practice frequently permits their use under heavy embankments, but demands sufficient size to permit of the insertion of enough iron or other pipe for permanent use. This may require as much timber as would an open trestle for the same place, but it frequently admits of depositing large quantities of earth in permanent embankments, instead of wasting it, or it may prevent delay. Otherwise, open trestles are usually preferred, as being cheaper than both culvert and embankment, and as admitting observation as to the necessary waterway. The western climate is as yet untrained to habits of uniform propriety. Pipes of iron, beton, or vitrified clay, are often used in first construction, if the condition of transportation permits, and commonly for renewals. Iron ranks as first-class work; the others may also, under proper conditions. Iron pipes, rejected from water-works' service for minor defects, are usually good enough.

Stone culverts are usually rectangular, of short span,—from 2 to 4 feet—single or double, built of rubble, either dry or in cement mortar, with flat covering stone, sometimes strengthened by the insertion of old track rails. Dry rubble walls are generally nearly as thick as they are high, and require better stone than is usually found at reasonable cost. When laid in cement, the following rule gives safe dimensions, viz: where h = height of opening, and s = span of same.

$$\text{Top thickness of wall at end in feet} = 1.5 + \frac{\sqrt{s} + h}{4},$$

batter on back 1 in 6. Make wall at mid length $\frac{1}{2}$ foot thicker for each 10 feet of filling over culvert. The walls are heavy, but our stone is generally small, and, if large stone is procurable, its specification would usually increase the cost more than the additional yards required for rubble work. The cost of such work is from \$3 to \$5 per cubic yard, depending largely upon that of transportation. There are thousands of miles without a stone structure.

Arched culverts of ten or more feet span, are occasionally used in permanent work, but ordinarily, proper foundations for such culverts are very costly, and streams of such size are very liable to carry highway bridges and other large drift at times, and this renders the use of such culverts of questionable wisdom. The formula :

$$\sqrt[3]{\text{acreage}^2} = \text{area of opening},$$

is used considerably for determining the necessary waterway. It is all right for the majority of cases in the flatter countries, but may give insufficient waterway if the waters collect suddenly, and this depends upon the more or less uniform length of the several head branches, the slopes, etc.

The construction of timber trestles and their necessity are too obvious to require dwelling upon. Formerly, mortice-and-tenon joints were used exclusively, but present practice is advancing to the use of drift bolts. Up to a height of about 16 feet, pile trestles are preferred, the height being usually limited by the quality of piles procurable. Excepting the removal of the bark, piles are driven in natural condition. Pile drivers usually have leads of about 40 feet, and the hammers weigh from 1,800 to 2,200 pounds. Horse-power is generally used. Two teams alternately raise the hammer by pulling straight away from the machine at the end of the fall rope. The usual penetration, in upland soils, is from 12 to 15 feet. The pile heads are usually banded, but the practice is not satisfactory. Wrapping with telegraph wire, tightly drawn, is more so, but the cast-iron follower is the best. It closely resembles the hammer in weight and shape, is somewhat concave on its lower side, and holds a piece of the pile head in its top, upon which the hammer falls. Its use expedites the work, and effectually prevents the brooming of the pile. Good piles seldom require iron shoes. When they do, iron straps, crossed on the pile tip and secured to the sides of the pile, are best. In soils filled with boulders, a dynamite cartridge, exploded in a drill hole some feet deep, where the pile should stand, would usually suffice to admit of sufficient penetration, when it would be impossible with the ground in its natural condition. A sharp point is usually detrimental. In quicksand, the water-jet system is the only one prov-

ing successful among the several tried, and it is entirely so. In using it, the settlement of the pile should be controlled, preventing the weight from resting upon the pile point until the pile is deep enough. Constant inspection of pile-driving can rarely be dispensed with. Formulas for the bearing power of piles in trestle work are of but little use. The variation in the adhesiveness of soils, under different conditions of saturation and as affected by vibration, renders nice calculations futile and absurd. Good practice will not allow the punishment of good timber, which is common under arbitrary rules. As long as the pile goes without marked change in penetration, or punishment, we drive it, but ordinarily, if the penetration of a good-sized pile gradually decreases to about 2 inches, under the full fall of the hammer, it is pounded enough. In ordinary upland soils the depth driven should be about 14 feet, in deep alluvial valley soils from 2 to 4 feet deeper. Probably 4 feet additional depth would warrant accepting one inch less penetration under the last blow. There is need of large experience and excellent judgment in driving piles. They are seldom straight, or of uniform size.

Conditions of "no brooming," "no spring," etc, theoretically required, are never attained. The condition of the soil varies largely with the season, etc. For equal energy, the blow of a heavy hammer is more effectual than that of a light one.

Piles will at times settle after bearing traffic for a year or two, while under other conditions they will be firm when but slightly pounded in driving.

The usual price of piles lies between 35 and 50 cents per lineal foot of length as billed. Transportation, and the distribution and size of bridges, largely control the cost. Framed timber, in trestles, is paid for per 1,000 feet board measure, and from \$25.00 to \$35.00 per 1,000 feet are ordinary prices. The bolts, washers, etc., generally cost from 4 to 6 cents per pound. The quantities of timber and iron used may average about as follows, as the memorandum is reduced from a large number of bridges. Spans 16 feet, 4 piles to the bent :

Pile bridges, height from 2 to 22 feet (average about 12 feet).

Per span.	Piling	105 lineal feet.
" "	Framed timber . . .	2,038 feet B. M.
" "	Wrought iron . . .	107 pounds.
" "	Cast " . . .	153 "

Single-deck framed trestles, 16 to 35 feet high (average about 24 feet).

Per span.	Piling	83 lineal feet.
" "	Framed timber . . .	3,286 feet B. M.
" "	Wrought iron . . .	122 pounds.
" "	Cast " . . .	172 "

Two and three-decked trestles from 41 to 65 feet high (average about 48 feet).

Per span.	Piling	79 lineal feet.
" "	Framed timber . . .	5,024 feet B. M.
" "	Wrought iron . . .	143 pounds.
" "	Cast " . . .	268 "

The average percentage of cost was :

	First type.	Second type.	Third type.
Piles	38 per cent.	24 per cent.	17 per cent.
Timber	51 " "	66 " "	75 " "
Wrought iron	5 " "	5 " "	4 " "
Cast "	6 " "	5 " "	4 " "
Average cost per lineal foot .	\$8.35	\$10.30	\$13.91.

Average prices : Piling, 48 cents ; timber, \$33.00 ; wrought iron, 6½ cents ; cast iron, 5 cents.

Bridge work is generally done in great haste, as the material comes from great distances and over the newly-laid track, and a race between the bridge men and the track layers is the usual programme. Good management and first-rate workmanship are here especially conspicuous when they occur. To secure the latter, and for other reasons, timber is not usually accepted until it is properly placed in the structure and the whole structure is properly completed. For several reasons large margins of strength are provided.

The display of energetic action and extravagantly hasty work often culminates in the track-laying. Previous delays have to be made up, investors thirst for income. The forces employed are very large, delays are costly, and no single imperfection of grade seems important enough to hold the track. Grading contractors are often artful in avoiding the finishing touches. Track-laying bosses are adepts in swelling extra bills for delays, and, as a class, are aggressive crowdors of the "small fry" in their way. Narrow, rough, unditched road-beds too frequently result, and costly material, easily damaged, is hastily thrown down in the vicinity where it belongs. Cross-ties are taken by the construction train to end of track, tumbled off and hauled ahead by teams. A long line is stretched 4 feet, or workman's boot-lengths, from the center, and the ties lined thereby at one end, the joint-ties being first spaced by measurement. The rails and fastenings are loaded on a low, strongly built push-car, with rollers at each corner, and this is hauled to the front by horses. Men pull out rails at each side at the same time, and drop them. They are held, by bars, nearly enough to gage, to hold the iron car up, and the car is shoved ahead another rail length, fastenings being dropped at proper intervals. Joint-splicers and spikers

follow; joints, centers and quarters are first spiked to gage—more or less carelessly; the expansion joints are regulated by bits of wood or iron wedges, and their regularity is immediately destroyed by the throwing of the track to line, or as nearly to line as may be guessed, after the preceding operations have knocked out the engineers' stakes. Surfacers and fillers follow the liners. The best material that is extremely handy is filled in, and often the destruction of the track promptly begins by drawing spikes to raise the track, etc., but it is finally yanked into respectable line and surface, pronounced splendid, and turned over to the operating department, which has a lively wrestle with settling banks, kinked rails, bad gage, mud ballast, etc. In this work each man has certain motions to make, and progress is rapid, and this fact covers a multitude of sins. Records of over eight miles per day during daylight have been made. Happily, the use of this rough process is becoming rare, as extensions are more deliberately constructed by large systems that propose to operate them, and as track is laid by company foremen, instead of by contract per mile. Still, these foremen are judged rather by the daily progress made than by the maintenance expenses following, and nicety is not indulged in to great extent. Track-laying machines, by which all the material is drawn from the front end of the front car of the construction train are used to some extent. The front car is pushed onto the last rail length laid, as soon as it is partially spiked. Their use does not allow of surfacing before the locomotive passes over the track, and usually only part of the ties are first put in place. The machines are extolled, or deprecated, in various degrees. With them progress is limited to about three miles per day. Contract prices for track-laying, filling and surfacing (the track material being provided in material yards), ranges from about \$325 to about \$500 per mile. Probably \$300 per mile will about cover the actual cost of labor in a force laying two miles per day in open country.

From this outline of professional practice in the front ranks of scores of millions of struggling founders of a new civilization, preparing for them a way, do you gather that our ways are crude and our practice rude? They are not more so than the dictates of uncontrollable circumstances compel. Kid gloves and hair-splitting niceties have been eliminated, 'tis true, but brains and untiring energy and physical powers have won the race. In the mighty rush of events which constitutes our domestic history, the coming of the railway engineer has been the first omen of the incoming tides of people, the first signal that a new channel for the bounding pulses of a young athletic nation was to be carved. His indomitable energy has made easy of access boundless treasures of wealth, locked in solitude since time began. Before him traditional deserts have vanished and bountiful harvests have followed closely

behind. From his footprints bright visions of fond hopes realized have ever blossomed. New-found homes for eager multitudes have sprung into beauty along his path, and eager thousands have quickly clustered around the centers which his keen foresight has first discerned and marked.

Nor has his pace been slow! Eight times in a century would it tame a wilderness of the combined areas of Great Britain, Ireland, France, Switzerland, Austria, Prussia, Spain, Portugal, Italy and Egypt. The swiftest denizens of our plains have been surrounded, and fields of grain have hidden the trail of the savage before he found a refuge. The restless, wiry "peg sticker" of our times has been a "potent simple" in the magical charm which has won the world's brightest land of promise from an obscurity as deep as time has been long. He has been here! he is gone, and is well nigh forgotten, but Chicago and scores of fair cities and immense regions filled with homes of comfort, bedeck his pioneer way.

ON THE BEST ARRANGEMENT OF LONGITUDINAL BRACING FOR TIMBER TRETTLES.

BY M. E. YEATMAN, MEMBER OF THE ASSOCIATION OF ENGINEERS OF
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[Read November 10, 1894.*]

FIGS. 1 and 2 show the standard form of timber trestle work in use by the Norfolk and Western Railroad. In its general features this standard has been in use for many years, but it has been subject to such modifications as have been found desirable from time to time, either in the way of increasing the strength to correspond with the gradually increased weights of rolling stock, or of making such changes of detail as the practical experience of those concerned with the maintenance and renewal of these structures has suggested as likely to increase their durability or facilitate the necessary renewals. Under the first head, the size of the stringers, spur braces and longitudinals has been increased; under the last, the divided sill of two pieces, 6x12, instead of one 12x12, has been adopted, as these can be replaced without the necessity of either cutting off the tenons on the posts or raising the trestle bodily the depth of these tenons, as must be done with posts mortised into a solid sill.

Among such suggestions for improvement one has been received relating to the arrangement of the longitudinal bracing, and proposing to place this upon the outside line of inclined or batter posts, rather than upon the second line from the outside, as shown by the present plan. The present paper embodies an attempt to determine, from theoretical considerations, whether such a change would be an improvement or the reverse.

Let us for a moment trace the functions of the different members of the structure:

The vertical posts carry the loads, and the stringers are proportioned to the bending action of loads supported between the posts. These parts are essential in all cases. Then, to resist the transverse action of wind, or of centrifugal force on a curve, we have the inclined or batter posts, and these, with the caps and sills to hold them together, form all that is absolutely necessary in trestles of small height. It is usual, however, in all but very low trestles, to add face bracing or X bracing on each bent to secure the trestles from rocking sideways in the mortises as they would otherwise be liable to do, owing to the small inclination of the batter posts; and also to provide longitudinal bracing to resist the

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longitudinal force arising from the acceleration or retardation of trains on the trestle, for which we should otherwise have to depend on the continuity of the stringers, and on the end sill as an anchorage. As this end sill merely rests on the bank and has no great weight on it, such longitudinal bracing is generally required, but its function, in single-story trestles, is merely to keep the bents upright, and it does not seem to be a matter of much moment whether it be attached to the vertical or to the inclined posts, since the point which it will secure at the top of the trestle is nearly the same in either case. On the whole, as the vertical posts may be supposed to carry the heaviest load, they probably afford the best fixed point at the bottom from which to brace; and the braces will be also of slightly less length if used in the vertical plane; but this latter difference is very small.

When we come to consider trestles of a much greater height, an entirely new set of circumstances arises, for now the vertical and inclined legs are too long to be cut from single timbers, and, if so cut, they would be deficient in rigidity, under compression, unless greatly increased in cross-section. They are therefore made in lengths of from 20 to 25 feet, abutting against one another, but practically offering the conditions of two or more rigid pieces connected by joints hinged in all directions. It therefore becomes necessary, for stability, that each joint be fixed in place, this condition being secured if the joint be held firmly against motion in two directions at right angles to one another. This must be effected by proper systems of transverse and longitudinal bracing.

The transverse bracing is comparatively simple, since it is necessarily applied to every bent and in each story. It must not have so steep an angle as to become ineffective, and it is for this reason that the top story is limited to 20 feet in height instead of 25, and when, in the lower stories, a single brace would become inconveniently long, two or more are used. It is immaterial to which particular points at the top of each story the bracing is carried, for, when any one or more points are duly fixed, the intermediate caps or horizontal walings afford a secure brace against any transverse motion of the remaining points.

The circumstances of the longitudinal bracing are different, for, in order to secure a similar fixing of every point against longitudinal motion, it would be necessary to apply bracing to every set of posts just as transversely it is applied to every bent. This would involve the use of a great number of long and heavy timbers, and it is not necessary; for if we fix a certain number of the points in each story, we can still rely on the intermediate caps to keep the others approximately in place. I say only approximately, for we are now depending on the stiffness of the transverse pieces against bending, and this is a different matter from their effectiveness as direct struts or ties.

In the one case we have their length practically unchangeable: in the other, not only a quite appreciable yielding to any external bending forces, but their liability to assume, by spontaneous warping, a curvature sufficient to throw the unbraced points visibly out of line. Granting then that some of the posts in each story must be left unbraced, and thereby liable to get slightly out of line, the practical question is: which of the posts can be so left with the least damaging results?

The plumb posts, as carrying the direct weight of the trains, are the most important, and it is assumed that bracing will be applied to them; but this alone is not sufficient for (1) although these two points be absolutely held in place, the others, in the same bent and at the same story, may be considerably thrown out by curvature of the intermediate caps (see Fig. 3); and (2) in a high trestle the distance between the two plumb posts is so small, as compared with the whole width, that a very minute displacement of either of these will cause (even without any curvature) a serious displacement of the outer posts unless some of these are separately braced (Fig. 4).

The present practice is to brace also the second line of batter posts, thus fixing the points O , O^1 and Q , Q^1 (Fig. 5) and leaving P , P^1 and R , R^1 liable to slight displacement.

The suggested change would be to transfer the bracing from Q and Q^1 to the outermost posts, thus fixing the points R , R^1 , as well as O , O^1 , and leaving liable to slight displacement P , P^1 and Q , Q^1 (Fig. 6). To compare the displacement, we will call the lengths OP , PQ , QR , x , a and b respectively. Of these, a and b are constant, while x varies with the height of the trestle above the story considered.

Now assume Case 1 (Fig. 5) in which the points O and Q , in one half of any given intermediate cap, are fixed, and let the displacements of P and R be called p_1 and r_1 ; and Case 2 (Fig. 6) in which O and R are fixed, and let the displacements of P and Q be called p_2 and q_2 . In either case the amounts of these displacements are to be limited by an assumed maximum curvature whose radius is C . Then we have (approximately, so long as the radius C is large)

Case 1 (Fig. 5).

$$p_1 = \frac{a x}{2C}$$

$$r_1 = \frac{b(a + b + x)}{2C}$$

Case 2 (Fig. 6).

$$p_2 = \frac{(a + b) x}{2C}$$

$$q_2 = \frac{(a + x) b}{2C}$$

Now, since all these quantities are taken as positive, p_2 is always $> p_1$ and $r_1 > q_2$. Also, $p_2 > r_1$ if $(a + b) x > b(a + b + x)$, if $ax > (a + b) b$, or if $x > (a + b) \frac{b}{a}$.

This, then, is the condition which must be fulfilled in order that the proposed arrangement may allow a greater displacement at any one point than the present one, and it depends on the height of the trestle above the line of caps under consideration; for (calling this height H .) the lengths a and b are constant ($= 62$ inches and 50 inches respectively in the plan shown) and x is $= \frac{5}{24} H - 105$ inches (the batter of the posts being $2\frac{1}{2}$ inches to 1 foot).

This makes the above condition

$$p_2 > r, \text{ if } x > \frac{112 \times 50''}{62} = \frac{2800}{31} = \text{about } 90 \text{ inches}$$

$$\text{or } \frac{5}{24} H - 105 > 90 \text{ inches, or } H > \frac{24}{5} \times 195 \text{ inches or } > 78 \text{ feet.}$$

Thus, for all cases in which $H < 78$ feet, including all trestles of four stories or less, the proposed change would be an improvement, as judged by the criterion of the smallest displacement of the most unfavorable point.

We can, however, go a little further, and consider, not simply the relative amounts of such displacements due to a given amount of warping of the timbers, but the results thereof. For, as soon as any given joint is thrown out of line, there results a tendency to be forced further out, a tendency proportional to the amount of such initial displacement and also to the compressive strain on the leg in question. The horizontal resultants produce bending moments on the horizontal caps, and the relative amounts of these moments measure the relative danger of collapse in given cases.

Now the maximum sideways bending moment in Case 1 may occur either at Q or at P ; and, if we put P , Q and R for the vertical loads at these points, these moments may be expressed by

$$M_q = k R r_1 b = k^1 K b^2 (a + b + x)$$

$$\begin{aligned} \text{and } M_p &= k R r_1 b \frac{x}{a+x} + K P p \frac{a x}{a+x} \\ &= \frac{k^1}{a+x} (R b^2 x (a + b + x) + P a^2 x^2) \end{aligned}$$

in which k is a factor common to both expressions and depending on the assumed limiting curvature and on the length of the posts in each story, and $k^1 = \frac{k}{2C}$.

The values of P and of R cannot be exactly determined, since we have no means of finding the exact distribution of the load between the different posts, but it is reasonable to assume that the loads are proportional to the sectional areas of the posts, or as 10 : 12.

Assuming this, and using the values given above for a , b and x , we find that M_q or M_p is greater according as H is less or greater than 83 feet.

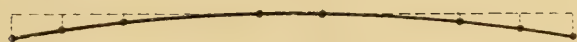


Fig. 3



Fig. 4

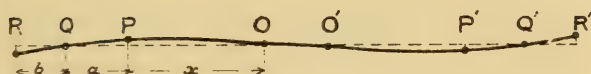


Fig. 5

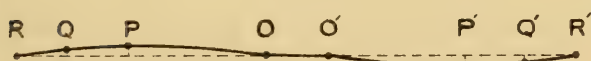
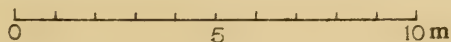
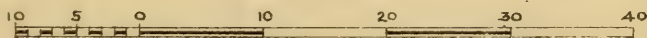


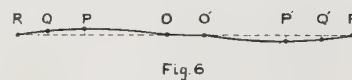
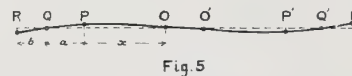
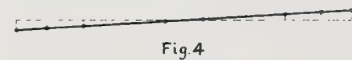
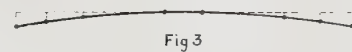
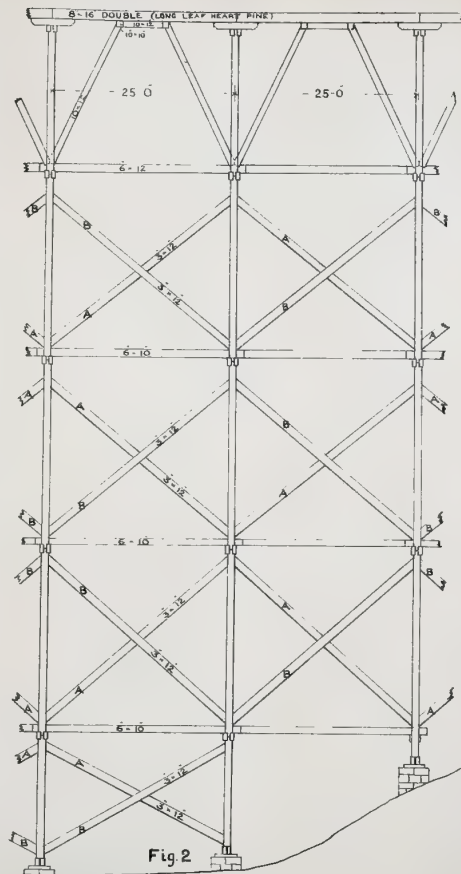
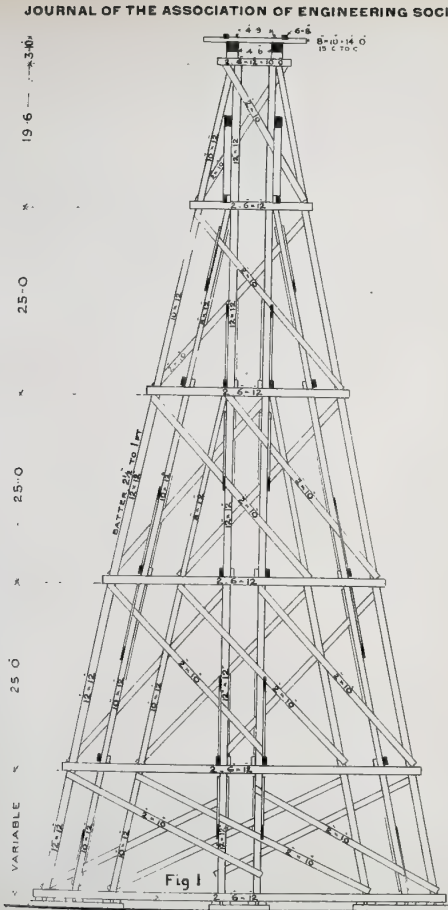
Fig. 6

LONGITUDINAL BRACING FOR TIMBER TRETTLES

BRACES MARKED **A** IN FIG. 2 ATTACHED TO PLUMB POSTS, THOSE MARKED **B** TO BATTER POSTS.

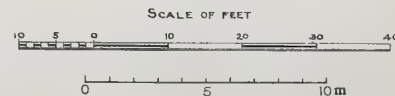
SCALE OF FEET





LONGITUDINAL BRACING FOR TIMBER TRETTLES

BRACES MARKED **A** IN FIG 2 ATTACHED TO PLUMB POSTS, THOSE MARKED **B** TO BATTER POSTS.



This shows us where to find the most unfavorable point in Case 1. In Case 2, for all trestles of considerable height, the point P will be the most unfavorable, and the corresponding moment M_2 will be expressed by

$$M_2 = kP \rho \frac{(a+b)x}{a+b+x} + kQq_2 \frac{b(a+x)}{a+b+x} \frac{x}{a+x} \\ = k' \frac{1}{a+b+x} \left\{ P(a+b)^2 x^2 + Q(a+x)b^2 x \right\}$$

Inserting the values of a , b and x , and making similar assumptions as to the values of P and Q , we find, on comparing M_2 with Mq , that M_2 is the less so long as $H < 80$ feet, but that, when $H > 80$ feet, M_2 becomes greater than Mq , and that, as Mp does not become greater than Mq until $H > 83$, Q is in Case 1 the critical point with which to make the comparison.

Our conclusion is, therefore, that for trestles in which $H > 80$ feet, the proposed change would be an improvement, a result slightly more favorable to the change than our previous one, based on the displacements alone.

Now, in standard four-story trestles, $H = 70$ for the lowest line of intermediate caps (that is the height of the three upper stories is 70 feet, the bottom story being variable), and for all such trestles the change is shown to be an improvement.

For trestles of five stories, H would be 95 feet from the top of the bottom story, and in this case the change would be for the worse, so far as the bottom story is concerned, although for the better as regards the upper stories. But, of course, the bracing must be carried continuously down to the ground on any line of posts which is braced in the upper stories.

The following plan is therefore suggested for all trestles of two or more stories: Apply longitudinal bracing to the plumb posts and to the outside batter posts; and, in trestles of five or more stories, use, in addition, a set of bracing on the innermost batter posts of all stories below the fourth from the top.

This makes an improvement, at no additional expense, in trestles of two, three, or four stories, and, in trestles of five or more stories, it makes a great improvement in the lower stories (which are the most severely strained) by the addition of a set of longitudinal braces in one story of five-story trestles and in two of the stories of six-story trestles, and so on, if any of still more formidable height than 150 feet should be constructed.

The timber, in a trestle 120 feet high, would, by this change, be increased from 829 feet B. M. per lineal foot to 849 feet; and, in a trestle 150 feet high, from 1059 feet B. M. per lineal foot to 1099 feet, an increase of 2.4 and 3.8 per cent. respectively.

THE RELATION OF TECHNICAL TO LIBERAL EDUCATION.

BY DR. C. M. WOODWARD, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read November 21, 1894.*]

THIS discussion encounters two serious difficulties at the start: First, the definition of technical education; second, the definition of liberal education.

I. Etymologically, "technical" ought to include all arts as opposed to all sciences. But we all know that, beyond vague general suggestions, etymology is a very poor guide to exact meaning.

The Greek word *techne* suggests too much on the one hand and too little on the other. In the first place, we must omit all linguistic arts. Then, the trades are not "technical," as the word is used in this report. Iron-workers, wood-workers, cloth-workers, stone-cutters, leather-workers, glass-workers, and the like are not technical people.

"Technical" education always involves the application of the exact sciences to the arts of life, and every technical study needs the use of the higher mathematics, the principles of physics and mechanics and the aid of exact drawings. Thus, technical education belongs to the higher education. However, the fine arts of painting and sculpture are not usually included in technical education, though they lie very close to it, since they make careful study of form and of its representation, under the general heads of orthographic, isometric and perspective drawing. While technical education includes organic and inorganic chemistry, it does not include the preparation of drugs. It includes the general theories of ventilation and sanitation, but does not include the arts of nursing and healing. The arts of war on land and sea are highly technical, but in the United States these arts are taught by the general government exclusively, at Annapolis and West Point, so that they may be omitted from this discussion. None of us thinks of a naval or a military school when "technical" education is mentioned.

It thus appears that technical education is limited to substantially the following arts:

(1) Civil engineering, which deals with the construction of roads, streets and bridges; with geodesy, *i. e.*, the measurement of land and the making of maps; the construction of canals; the improvement of rivers and harbors; the building of dams, waterworks, reservoirs, sewers,

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dikes, etc. This range is so vast and comprehensive that it has been subdivided many times, and one hears of hydraulic engineering, sanitary engineering, bridge engineering, geodetic engineering and of railroad engineering. The content of engineering is constantly increasing, as the exact methods of science replace the wasteful and clumsy methods of tradition.

(2) Mechanical engineering, which deals with the construction and erection of prime movers, such as water wheels of all kinds; steam, air and gas engines and windmills. Next, the immediate connections of these, such as pumps, fly-wheels, shafting, saw-mills, flour mills, rolling mills, elevators, hoists, furnaces, machines, and tools of all kinds, sizes and uses.

It is evident that the scope of mechanical engineering has widened rapidly ever since it adopted scientific methods and took on the dignity of a profession. People generally have a very inadequate notion of the functions of a mechanical engineer. To be sure, he knows the theory and uses of tools and the properties of materials, just as the graduate at West Point knows by actual practice how to handle a musket, how to pitch a tent, how to load a field piece and how to keep a camp clean; but when he is in the practice of his profession it is his function, as it is the function of an army officer, to plan and calculate, and to direct men. When the civil engineer, Monsieur Eifel, built his famous tower, does any one suppose that he put his hand to a single bar of steel as it entered into that elegant structure, which was as exactly calculated as are the motions of the moon? When Engineer Ferris erected his monster wheel, does any one suppose that he struck a single blow or lifted a single ounce of it with his own hand?

Please do not suppose that I am saying this for the purpose of showing how genteel a profession engineering is. I am concerned only with correctness of definition. A mechanical engineer is not an engine driver nor a machinist; any more than a city superintendent is a classroom teacher. An engineer, if properly trained, could "run" the engine, or handle a tool, as the superintendent could conduct a recitation, and do it extremely well, too, if there should be occasion, but that is not his business.

I hardly need add that there are many excellent workmen who are anxious to be considered engineers, in the sense in which I use the term, as a product of technical engineering education, but who lack the broad training which is strictly essential to such consideration.

(3) Electrical engineering, which includes the theory, science and art of construction, erection and maintenance of all the devices of dynamic electricity—generators, motors and the means of electrical transmission. This is the youngest of all the technical professions, and

yet it is one of the most difficult. The problems involved are among the most profound and intricate. Though dealing only with one form of energy, it already covers an immense field, and its boundary is receding rapidly on all sides. As you well know, there is an army of electrical workers, but the number of thoroughly trained electrical engineers is small. I doubt if there are 500 in the United States. The need of them is very great, for a great deal of our electrical work is very wasteful.

(4) Architecture, which includes the design and erection of buildings for all sorts of uses and of all sorts of materials. This is the oldest of the technical professions, but its modern developments make it almost new. So long as stone was the chief material used in buildings, and only churches and palaces were supposed to have any architecture, the problems of the architect were those of masonry and surface ornament; it was a question of columns, capitals, entablatures and arches. Modern architecture constructs with steel pillars, steel girders, steel trusses; and, though surface decoration (often of the most illogical sort) is introduced, the skill of the designer is largely spent on the details of plumbing, heating, ventilating, lighting and grouping. We insist to-day on having what the private citizens of Athens and Rome never had, homes of grace, comfort and convenience. The introduction of steel and glass and hoisting machinery demands new styles, new orders. The great need of architecture to-day is freedom. It must be liberated, set free, from the slavery of styles which were appropriate only to stone. We see the effects of this bondage in such incongruities as iron pillars that pretend to be blocks of stone, and a rigid frame of steel with a veneering of brick.

The coming architect of steel must be near at hand. Harvard recently gave an honorary degree to the man who designed the Masonic Temple of Chicago.

(5) Chemical engineering, which includes the departments of metallurgy, gas, the occurrence and the treatment of ores, minerals and clays, and the production of valuable compounds. It is evident that the chemical engineer is a factor of growing importance in every highly developed community. The energy, which appears under the two closely related forms of light and heat, is the special form which the chemical engineer employs, as the alchemist of old would have used the philosopher's stone, to transmute dross to gold. With these magic wands he unlocks the secret store of nature and increases the riches of the commonwealth.

It is evident that these various branches of engineering overlap each other at many points; for they form, not isolated areas, but the continuous and ever enlarging circle which bounds the domain of science and marks the conquest of human intelligence over the arcana of the material world—the victory of the known over the unknown.

There are other arts, like those of agriculture and horticulture, which, while embraced under the general term of biology, rest more or less upon the exact sciences, and hence admit of systematic presentation. They belong to the ground common to mechanical and chemical engineering. Farming is getting to be largely a matter of machinery, and the problems of soil, climate and plant culture are those of chemistry. The agricultural engineer has not yet been born. Farming is not yet a profession. It is rather a trade, with a maximum of art and labor and a minimum of science.

Again, usage puts into technical education far more than mere art, for every technical profession, properly so-called, is both a science and an art. Hence, all pure science is tributary to technical education, though, of course, not equally to all branches. A technical school is, first, scientific; and secondly, professional. The relation of applied science to pure science may be illustrated by the relation of Greek and Latin literature to the study of Greek and Latin Grammars. The eminent value of one is that it leads to the other. The Roman soldier was trained in the use of the spear, the shield and the short sword because he was expected to use them; the modern soldier expects to use repeating rifles and Gatling guns, and he is trained accordingly. Technical education is equally logical.

Finally, a "technical" course of study includes a great deal that is not technical at all, but which nevertheless must be taken into account when speaking of technical education.

Take, for instance, the technical courses in the Science of Engineering in Washington University. They are invariably four years long, with a possible fifth, or graduate year. Freshmen enter with a knowledge of algebra, plane and solid geometry, the elements of drawing, elementary physics or chemistry, American and English (or ancient) history, two or three years' work in Latin, German or French, and a passable knowledge of English.

The curricula are very similar to corresponding curricula in the Massachusetts Institute of Technology and Cornell University. From sixty to seventy per cent. of all such courses is found in the courses for bachelor's degree of all first class colleges, and in some, the proportion is still greater.

This common, non-technical material consists of modern languages, mathematics, mechanics, rhetoric, literature, physics, chemistry, geology, mineralogy, political economy, astronomy and elocution.

When a college is able to offer a large variety of electives they are more often taken from technical courses, though scarcely technical themselves, such as descriptive geometry, surveying, drawing, applied mechanics, theories of structures, electricity, and the like.

An examination of the last catalogue of Harvard shows that its course of instruction offered to the candidates for the degree of A. B. contains 87½ per cent. of our course in civil engineering, 75 per cent. of our course in mechanical, 94 per cent. of our course in electrical engineering, and 100 per cent. of our course in chemistry. In like manner our own A. B. course includes nearly all of our technical branches.

II. Thus far I have considered the limitations, and, again, the greater extensions of technical curricula. I have now to consider the character, meaning and content of "liberal education." Undoubtedly, it is a very loose term, and no two of us would wholly agree on its definition. Originally, a liberal education was that course of training which was befitting a freeman and a gentleman as contrasted with a slave's education to labor. The aim, to quote Webster, was "amusement, curiosity, intellectual improvement, rather than the necessity of subsistence." So long as direct utility was in view, it was not liberal. Education began to be liberal as soon as it got beyond the idea of immediate use. Hence, Lowell is said to have defined a university as a "place where nothing useful is taught."

I do not know in what connection Lowell uttered these words, but by "useful" he must have meant "directly and immediately useful for earning a living and limited to such use," otherwise the statement would be as ridiculous as it is extravagant. Is there anything in science, in art, in history or in literature, which, when thoroughly comprehended, has not a probable or a possible use? There are uses and uses; primary, secondary and ultimate uses; higher uses and lower uses; immediate and remote. The phrase "thoroughly comprehended" has a saving grace. It makes things useful which otherwise were useless. The most useless things in the whole world of education are things imperfectly learned; things taken up, then not mastered, but laid aside. Do we not tolerate too many of these useless things? So impressed am I with the utter worthlessness of much that is called "liberal" that I would define a true university as a "place where nothing useless is taught."

The word "liberal," in modern education, refers, not so much to the subjects studied, as to the method of studying them. The liberal method is broad, deep, generous, comprehensive. It is not limited to mere immediate use. It recognizes use only as the greater includes the less, but it is not limited to it. That thorough mastery of a subject which makes it available for all possible uses, necessarily includes the near as well as the remote. The liberal method aims at the artist rather than the artisan; at the engineer rather than the craftsman; at the head rather than the hands. Liberal culture deals with fundamental principles, typical phenomena; with general results, not special

applications. It is liberal to study, under the head of political economy, the laws of manufacture, trade, commerce, finance, supply and demand; it is not liberal to learn merely the conditions of a successful business in a given community at a given time.

The list of liberal branches is ever increasing. When I was at Harvard I was compelled to give one-sixth of my time to Greek and one fourth to Latin. I studied political economy for a single term. I never entered a laboratory except to sit down and listen. I did not do a stroke of drawing. I did not even know that there was a science as well as an art of drawing, and that its name was descriptive geometry—a sadly neglected study, which affords more mental discipline in a given time than any other study I know. I am glad to be able to testify that now, not only at Harvard, but at Washington University, and at scores of others, West and East, one may study Latin and Greek or not, as he chooses, and that everything in all sciences, arts and literatures admitting of systematic treatment, is offered freely to all who may choose, as a liberal course. People now study Greek and Anglo-Saxon, not because they are compelled to, but because they wish to, just as they may study mechanics or descriptive geometry or electricity, or thermodynamics. And they do not—or, at least, they should not—study them in any mean, superficial, perfunctory way, but broadly, comprehensively, with relish and enthusiasm. With such opportunities and by such methods all university work should be liberal, and all liberal work should be in the university. Do any suppose that our students are less liberally trained than formerly? The material of which college curricula are made has increased many fold since most of us took our degrees.

The adoption of these ideas has lifted, and is lifting, all the work to a new dignity. The college of letters is no longer a narrow school for the training of professional men.

Remembering the fact that, up to 1850, the purpose of our American colleges was to prepare men for the four professions of theology, law, medicine and teaching, we can see on what utilitarian lines the course of study was formed. The clergyman must read the New Testament in the original; the lawyer must read Cicero, Quintilian, and the "Institutes" of Justinian; the physician must read Galen, the professor must take Latin, Greek and mathematics. The plan was simple and reasonable.

Suddenly, a group of new professions appeared and struggled for recognition. The age demanded them, and it demanded, too, the introduction of new elements in education, just as liberal, just as closely touching life, society and progress, just as humanizing, just as logical in reference to the new demands, as the old elements had been in reference to the old demands.

A professional degree is a stamp placed upon the forehead of the graduate, declaring him worthy the confidence of those who may need the service of a doctor, or an engineer, or a lawyer. Before one can worthily receive such a stamp, he must be in possession, not only of a trained and vigorous mind, familiar with general laws, but of a large fund of exact information, much of which is matter of time and place.

Every technical course has more or less of this professional material, and just to that extent it differs from the highest type of liberal education. These facts of time and circumstance—dates, prices, statistics, etc.,—which to-day have value and to-morrow are ancient history, should ever be minimized in the presence of unchanging principles, general theories and inexorable laws.

It thus appears that, when we take into account the current meaning and the scope of technical education, and the full significance of liberal education, we find that nearly all of the ground is common, and that, even when the branches of study are different, the spirit and method are much the same.

I have had unusual opportunities to know what is meant by a high-grade technical course of training. I know how every subject is treated historically, empirically, experimentally and theoretically. Take the subject of bridges, and you will find that the evolution of the modern most finished types involves a history as long, an analysis as profound, and a variety as great as in the development of forms of government or of religious belief.

From stone arches, circular, segmental, elliptical and oblique, to tubular bridges, to truss bridges of many kinds, to steel and iron arches, to suspension bridges, and to the modern cantilever which spans 1,700 feet, is a very long story, full of the achievements of intellect, genius and daring. In the presence of such a history and exposition, a hundred matters, that men make much of in the records of human achievement, pale into insignificance. Before that history can be read intelligently, the laws that obtain in all operations involving force, motion, energy, mathematics and mechanics, must be so mastered that they are not a "memory and a forgetting," but are the keen-edged tools ready for use in a high analysis. He who reads aright the history of the great steel arch built over the Mississippi by Capt. James B. Eads at St. Louis, reads the history of a thousand bridges. Said one of the most highly cultivated men I have ever known: "To read the full history of such work is a liberal education."

I have mentioned but a single subject in the technical courses, and yet you see how far reaching it is, how closely it is connected with the development of our civilization, with the gradual mastery of mind over matter. When I first read Browning's pathetic little poem, "The

Grammarians' Funeral," I could not avoid the feeling that it was satirical. It was impossible for me to believe that he could sincerely admire one who had devoted so much of his life to the "business" of two Greek words of three letters each.

Accustomed as I was to an intellectual atmosphere where authority was at a minimum and where the conclusions of a sound logic were supreme, I could not bring myself to see either heroism or genius in an endless conning of texts and a grouping of passages. A better acquaintance with Browning, however, convinced me that the poem is the tribute of a sincere respect and admiration. I shall not quarrel with Browning. *De gustibus*, etc. I quarrel only with those who do not see the intellectual character, the dignity and the culture of the accomplished engineer; a man who has so thoroughly mastered the laws which govern the forces of nature that he is able to make them subservient to the needs, the comfort, the luxury, the refinement of our race.

It is very easy to see the sources of a widespread prejudice against technical training. The history of civilization has been the history of masters and slaves, of caste, of contempt for all labor and for all useful arts. No wonder that Plato held that the useful arts were degrading, for they brought one into the companionship of slaves, for even in Athens, every freeman lived in luxury on the labor of several slaves. Caste prejudices were equally strong in Milton's time in England, so that Milton places Memnon, the chief engineer and architect of the hosts of heaven, among the fallen angels. In spite of his energy, his knowledge of ores and their treatment, and his marvelous skill in construction,

He was headlong hurled
With his industrious crew to build in hell.

The technical professions are all less than one hundred years old. They are all evolutions from trades. The first mechanical engineers built their own engines, and the first electrical engineer built his own dynamo. There is, therefore, an odor of the shop about the names, and a reminiscence of men who were heretics as regards theory, but firm believers in practice.

We all know the intense squeamishness of the average college professor with regard to anything which savors of use. "Thank God, that department can never be made useful," said an eminent professor, speaking of a newly established chair in a State university.

A similar spirit would seem to have prompted Professor Patten, in an article on the "Educational Values of Studies" (see *Ed. Rev.*, Feb., 1891) to say that a study loses its educational value in proportion as its economic value increases. Hence, mathematics and electricity have less educational value now than when they were of less utility. This statement is so incredible that I give his exact words:

“With the increase in their utility they will be of less value in educating men. Whatever makes them more fitted for utility studies, makes them less fitted for general culture.” Again, he asked: “Shall a subject be taught with a view of making the student a master of it, and thus enable him to obtain a utility (*sic*) from it? or shall it be taught with the purpose of producing the greatest effect upon the mind and culture of the pupil?” Professor Patten would have no objection to making a student a master of a subject, provided he were sure that the mastery could be of no use to him, for then he would be educating a man as man, and the result would be general culture. But let it be discovered that that mastery enables one to solve a practical problem, to earn a loaf of bread, or to make two blades of grass grow where one grew before, and lo! the man is less a man, the mental effort becomes narrow and undesirable, and what he fondly hoped was culture turns out to be mere “expertness” and “adroitness.”

We have all met with similar arguments and prejudices, but one rarely comes across such a frank expression of them. Fallacies which have come to be hundreds of years old, die hard, and to some it is a species of educational blasphemy to call them in question. It is for this reason that the majority of readers probably accepted Professor Patten's statements as gospel truth.

But such a statement cannot be quietly passed in this discussion. The relation of technical to liberal is far more intimate and cordial than is commonly supposed. I assert with confidence, that whenever a mastery becomes technical through use it is still liberal and more nobly liberal, and that a study is useless in proportion as it fails of mastery. The introduction of technical subjects into elective courses usually called liberal, so well begun at Harvard and promptly followed in a dozen universities, has met with opposition on the ground that there is something in technical study, or in the atmosphere of a technical school, unsuited—or at least, less suited—to a proper discipline of the mind and unfavorable to the growth of character. Says Dr. Wm. M. Bryant (*American Journal of Education*, February, 1891): “The professional school necessarily directs the attention of the student mainly to success in its outward aspects. It is in the college proper, where studies are suited to discipline and develop a man as a man, that the conditions are most favorable for the growth of character.”

The assertion that in technical study the attention is mainly directed to success in its outward aspects, is based on a misconception. Much is made of useful applications because they serve as illustrations of general principles. But the only “success” the student is conscious of, is the success of his effort to thoroughly understand the science involved and how it is applied. That consciousness “keeps his mind alert, expectant

and enthusiastic." The zeal of the technical student is akin to the zeal of the student engaged in research in the laboratory, and you know well what that is. It is as far as possible removed from the thought of "success in its outward aspects."

The belief shown by Messrs. Patten and Bryant is widespread, particularly among those who have had no direct contact with technical work. I have seen both kinds of training intimately. I have seen them in separate institutions, and I have seen them side by side in the same institution. So far as relates to vigor of intellect and high character, the influence of technical studies is in no respect inferior to that of the traditional untechnical curriculum. On the contrary (and I am not alone in this opinion), there is a widespread and uniform degree of earnestness and zeal among technical students, rarely equaled in colleges which do not admit technical branches. The sense of responsibility, which accompanies the study of subjects which cannot be slighted without leaving a defective foundation on which to build later, is helpful to serious and steady work. On the other hand, I remember that, in my own college days, it was difficult to look upon much of the college work with any considerable degree of earnestness. It seems to be irrelevant. The idea of thoroughly mastering a subject so that one could base something else upon it, rarely entered the head of the average student. I recently met a college classmate as an officer in a technical school. We fell into conversation as regards the influence of technical study on the development of character. Said he: "The earnestness and manliness of these students has been a revelation to me. There was nothing like this when we were at Harvard."

I shall be very glad to hear what has been the effect of the introduction of technical studies at Harvard; what proportion of the senior elections are what are called technical, and what influence they have had on the character and scholarship of the seniors electing them.

The character and attitude of the educated engineer towards classical learning, has much to do with the estimation in which he is held by scholarly men.

The engineer is by nature an iconoclast. He has small respect for the traditions. He snaps his fingers in scorn at all whose chief pride and glory lies in their submission to the "tyranny of the ancients." He cares less for what has been than for what may be. His triumphs, his masterpieces, his heroes, his golden age, are all in the future. He walks forward, with his face to the front; not backward, with his face to the past. When Captain Eads proposed to build a steel arch over the turbulent Mississippi with a clear span of 520 feet, the timid worshippers of the past held up their hands in protest that there was no precedent for an arch of such great length. To this unworthy opposition

it was said proudly in reply: "The engineer makes precedents; other men follow them."

There is another aspect of the effects of our modern liberal technical training, which is somewhat new. In that graceful liberal culture, which we all so much prize and which we more or less unconsciously set up as a standard for others, we learned how the imaginative Greeks made gods and demi-gods to account for wonderful things. Beings with superhuman strength and skill turned the courses of rivers, built impregnable walls, bore messages faster than the wind, and subdued monsters, drained marshes and warded off disease. Not to know these things is now held to be wanting in the very elements of a liberal education. In these modern days, men have done all these things and more, in fact and not in fancy, and yet to know these modern heroes—men, accomplished, but in no way superhuman—who have dethroned the gods and put demi-gods to the blush, is held to be not liberal, and such knowledge exposes one to the suspicion of being too familiar with swarthy fellows who handle machinery and despise the ancients. Men are now struck dead by artificial lightning, while the thunderbolts of Jove are turned harmlessly into the earth by a Franklin, and the energy of which thunderbolts are made is harnessed to a car or a mill by an Adams or a Hopkinson or an Edison, and made to serve the peaceful ends of commerce and industry. The dreadful energy of a Maxim gun or of a dynamite cannon is far more destructive than the twanging of Apollo's silver bow and his whole quiver of arrows. The skill of an Eads, which turns the current of the mighty Mississippi and forces it to maintain a new deep channel into the sea, dwarfs into insignificance the labors of a Hercules. The ingenuity of a Morse and a Field sends messages to the antipodes in less time than Mercury needed for binding on his sandals. The roar of Mars could be heard by whole armies; now the whisper of a Brush is heard a thousand miles.

It is now the engineer who turns away the destroying monster, redeems the waste places, brings health, peace and security where there was pestilence and death. Shall not an accurate knowledge of the exploits and rational methods of these modern times and heroes be held to be an essential part of a liberal as well as of a technical education?

Is not the educational army changing front? Is not our new leader an engineer, rather than a philologist or an antiquary? We all believe in culture. The word is much abused; perhaps I have helped abuse it; but there is culture and culture. Whatever broadens one's intellectual grasp, extends his mental vision, purifies his mental taste, lifts him away from individuals to generals, builds rational ideals, is an aid to culture, and, *ipso facto*, is liberal. This high function I see in high-grade

technical education. I urge most earnestly that, as is done in many universities to-day, on the one hand, all narrow, petty, ephemeral matters, which have no logical bearing upon life, be eliminated, and that technical subjects in their most liberal form be incorporated into the college course as possible electives. No longer should it be true anywhere, as, according to the Emperor William, it is now true in Germany, that they have an overproduction of what are called "over-cultivated men," who, instead of being an element of strength to the State, are a source of weakness, being unfitted for life and its problems. The college student should have free access to all subjects liberally taught, which he may choose according to the quality of his mind or the promptings of his future.

To this end technical and liberal departments should be brought nearer together and unified as much as possible. The wall of separation should be thrown down.

The relation between technical and liberal education should be that of the French motto: "Liberty, Fraternity, Equality."

THE MANUFACTURE OF CEMENT FROM FURNACE SLAG.

BY HERMANN CRUEGER, MEMBER OF THE ASSOCIATION OF ENGINEERS OF VIRGINIA.

[Read March 28, 1895.*]

THE question as to what should be done with the refuse of manufacturing of all kinds, is one which for a long time has agitated the minds of the most eminent chemists as well as those of practical men, and is one of ever-growing importance. After use has been made of raw materials, the refuse is again turned into a raw material, the uses of which, after many years of trials and experiments, have in some instances exceeded in value those of the original product from which these raw materials were obtained. I need only call attention to the uses now made of gas coal tar, a product which, not so very long ago, was looked upon as entirely a secondary matter, and, perhaps, used only for preserving wood from decay. Aniline dyes, and other chemicals largely used for medicinal purposes, etc., etc., are now produced from it.

Cotton seed affords another well-known instance of how a substance which at one time was considered almost worthless has proven to be almost as valuable as the cotton itself. Quite a number of other products are now being utilized.

Furnace slag (in German *Hochofenschlacke*) has always been a source of trouble to furnace men, and I well remember the expression of an old friend of mine, who claimed that the location of a furnace should be chosen at a point where the disposal of the slag would be attended by the least possible trouble. Of late, furnace slag, where it can be had cheaply, is being used in ballasting the road-beds of railroads; and since the question of better roads has been agitated furnace slag is being used quite largely for road improvement; but the amount used is very small in comparison with the amount of slag produced. For a number of years experiments have been carried on, particularly in Germany, Switzerland and France, regarding the practicability of manufacturing an hydraulic cement from slag, and, after a number of failures, these have proven successful, particularly where improved machinery adapted to the work has been used.

To a large extent I am indebted, for the information on the subject of this paper, to Professor Tetmajer, of the Polytechnic School of Zürich, Switzerland, who has made this particular matter his study and embod-

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ied it in his admirable pamphlet entitled "Furnace Slag Cement," mentioned in *Engineering News*, of July, 1889, since which time I have given this subject attention and have obtained, from various sources, information convincing me that the manufacture of hydraulic cement from furnace slag in the United States would prove to be not only practicable but profitable, if properly conducted.

The uses to which cement is now being put are daily increasing in number, including concrete walks, concrete in fire-proof buildings, concrete for brick-paved streets, etc., etc., and there is no reason why cement, if manufactured cheaply, should not, in course of time, almost entirely supplant lime for building purposes.

From Prof. Tetmajer's pamphlet, above mentioned, I beg to quote the following extracts:

"The first attempts to make slag cement by machinery were made in 1879-80, at Chomdez, Switzerland. In addition to slag bricks made, ground slag was produced and was called trass. It appeared at the Swiss Exposition, where it attracted general attention from experts. Slag cements have been introduced mostly by the founders of the Slag Cement factory at Thale, by Mr. Boss, architect, Brunswick, and by Mr. Hermann, manufacturer of cement, at Thale.

"Every normal slag cement is made of granulated furnace slag, ground to a condition of dust, and of calcium hydrate in the form of powder. According to local conditions, there can be added to the slag-lime mixture further artificial or natural pozzuolanas, silicates, silicious or silico-alumina preparations.

Furnace slags are principally lime and alumina silicates, made as secondary products in smelting iron ore. The chemical composition and the chemico-physical condition of furnace slags vary with the proportions of the ore, fuel and fluxes, and with the smelting temperature. In general, we distinguish acid, neutral and basic furnace slags. The slag is called acid whenever an equivalent of acid contents contains less than an equivalent of the base. In the opposite case, slags are basic. The neutral slags are those intermediate products which are found only in exceptional cases. Acid slags are used principally in the making of slag bricks and in the preparation of road materials. Cooled in water, they furnish a so-called slag-sand, which is used for road-making and in making mortar. By blowing slag with steam, slag-wool, or mineral wool, is made. Since it has become possible to de-sulphurize slags, it has also been used in the cement, glass and pottery industries.

"The sand made by granulating basic slags, works as an hydraulic addition when mixed with slacked lime or powdered lime hydrate. Pressed into moulds, it furnishes bricks for surface construction, or for works under water.

"It has long been known that certain kinds of basic furnace slag, granulated and mixed with lime, acquire the property of hardening hydraulically. The nature of the effect of granulation is now beyond question. It was formerly supposed that granulation effected a partial molecular change, which might be called a decomposition of the slag; but furnace slags are not silicates in the ordinary chemical acceptance of the term. They are complex alloys which are decomposed when made fluid by steam or a strong current of water. Slag loses a small part of its sulphur and silica, and probably other matters are set free. These can, by taking up water, combine with lime and consequently harden. Treated with hydrochloric acid, granulated as well as ungranulated slags become gelatinous, the granulated more energetically than the others.

"According to its chemical composition, basic slag which has been properly granulated presents a varying appearance. The particles of sand resemble weathered granite. In this case the particles are mostly round and translucent. Some, however, are not translucent, and others resemble pumice. The surface of the grain is generally lustreless, sharp like quartz, although less sharp than the sand of granulated acid slag, which latter is in pumice-like pieces, having the characteristic glassy lustre. Other less valuable slags show, when granulated, a slightly glassy, earthy, dirty lustre. The color of slag-sand is generally grayish. Slag made while the furnace is in good heat is slightly violet, and, when ground up, reddish.

"Granulation, and with it the degree of usefulness, varies considerably. The less the pressure and the temperature of the slag and the warmer the water, the smaller becomes the chemico-physical effect of granulation. White, hot, thin (highly fluid) slag, leaving the furnace at a high pressure, is particularly fit for granulation; slags made from gray foundry iron, allowed to accumulate in the furnace and consequently tapped under high pressure, give the best results.

"The slag spout should be as short as possible, and the stream of water strong. The same slag, differently treated, gives a valuable slag sand, according as the slag is granulated when very fluid or when in a syrupy condition. Slag about to chill furnishes less valuable material and is similar to the sand made from a cold slag.

"Every basic slag has a certain lime limit within which it will preserve its shape as commonly cooled, and above which it will disintegrate. The slag dust made from slag in the latter condition is valueless for cement mortar, as shown by various experiments. The degree of effectiveness of a furnace slag depends chiefly on the proportion of lime to silica. Slags in which the proportion $\frac{Ca}{Si} \frac{O}{O_2}$ (lime to silica) sinks

to about 1.0, cannot be used for the making of slag cement. Under otherwise similar conditions, the lime capacity of a slag increases with the growing proportions of alumina to silica. The higher the quotient $\frac{Al_2O_3}{SiO_2}$, the greater is the amount of lime required to give more strength.

"The most favorable proportions are, approximately: lime to silica to alumina = 46 : 30 : 16. Good results are reached only when the slag is granulated when very fluid and in a strong current of cold water. To obtain a good cement, fine grinding is most important."

Particular attention must also be paid to the lime to be added proportionally to the ground slag. The lime should be slacked to a dry lime hydrate. In France the lime is slacked in baskets, which are filled with the burnt lime and dipped into barrels filled with water. The lime, saturated with water, is then thrown into heaps which are then covered with sand mixed with lime.

Later methods have, by the introduction of steam, considerably improved this crude manner of slacking the lime. The slacked lime should feel as fine as flour. For this reason it is recommended to grind twice; first alone, and then with the slag, as this will give a more perfect mixture. The slacked lime can be kept for a long time without losing its usefulness.

The results of the most exhaustive experiments have shown that cement made from furnace slag belongs to those hydraulic mortars which are particularly valuable for use under water, and in the soil or in a damp atmosphere.

In order to give an idea of the differences in furnace slag and in the analyses of different cements I beg to append here a table giving such information as I have been able to gather :

ANALYSES OF CEMENTS.

	James River, by V. M. I. Inst.	Fred Smith, Portland.	Fred Smith, Roman.	Engineering News.	Howard Fleming, Portland Imported.	Swedish Cement.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silica	49.5	25	22	30.56	23.63	21.25
Alumina	11.2	8	7	13.31	10.87	6.47
Lime	25.1	60	55	45.01	59.47	64.00
Magnesia	14.0	. . .	. . .	2.96	. . .	1.41
Oxide of Iron . . .	. . .	. . .	12	.25	. . .	3.43
Impurities . . . .	. . .	7	. . .	7.00	6.03	3.41
Total	99.8	100	96	99.09	100.00	99.97

ANALYSES OF SLAGS.

	Roanoke Iron Co.	Crozer Iron Co.	Pulaski Iron Co. No. 1.	Pulaski Iron Co. No. 2.	Pulaski Iron Co. No. 3.	Prof. Tetmajer (most favorable condition).
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silica	34.48	38	38	38	35	30
Alumina	26.30	9	11	13	17	16
Lime	30.29	35	34	32	43	46
Magnesia	6.27	16	13	15	1	. . .
Oxide of Iron, etc. .	2.37	2	3	. . .	2	. . .
Total	99.71	100	99	98	98	92

From the above table it will be seen that there is as much difference between the analyses of the different cements as there is between those of furnace slags. Referring to Professor Tetmajer's paper, however, we see that the slag should be basic, which means that the percentage of silica should be below 39 per cent., which is particularly the case with the No. 3 slag of the Pulaski Iron Company, and, as I understand this matter, there is no reason why a slag of this kind should not make a good cement if mixed with the proper proportion of lime.

In conclusion I beg to refer to the accompanying plate, showing a layout plan for a complete slag cement factory, as designed by Messrs. Pfeiffer Bros., of Kaiserslautern, Germany.

The slag is first conveyed through an arrangement of dippers *A* to the drying kilns *B*. After it is released from the kilns, at the foot of the ovens *C*, it is spread out for cooling; or, if it has been sufficiently cooled, it is passed on through another set of dippers *D*, to the "Jochum" mixer and separator *E*, and thence to the funnel *F*.

The lime, after having been burnt, is slacked, and is then moved up and down by means of the double elevator *G*. While undergoing this operation, it is contained in wire baskets, which are dipped in water by the elevator and again elevated. The lime is then dumped into the silos *I*, and here it must remain for a while, the longer the better. After the required rest the lime is taken from the bottom of the silos, and elevated through a shaft *K* to the second funnel of the Jochum mixer and separator. The Jochum apparatus answers the purpose of dividing the slag and lime in certain proportions and of mixing them thoroughly. The latter operation is performed by a mixing screw *M*, on leaving which the material is then carried by another mixing screw to the four horizontal ball mills *N*, where it is ground into cement. It is then ready for use.

The cement is carried by screws *O* to the storage bins *P*, where it remains until it is barreled or bagged for shipment.

The total estimated cost of the machinery of such a plant is about \$13,000. This estimate, however, could be considerably reduced by obtaining a majority of the machinery in the United States. The plant would produce 24,000 kilos per ten hours' work, or 36,000 barrels of 400 pounds each, per year, which of course could be doubled by employing a night shift.

That cement from furnace slag is coming into competition with the best Portland cement is a fact which can no longer be disputed. I quote from a pamphlet issued by Howard Fleming, 23 Liberty Street, New York, Importer of Portland Cement :

"Slag cement has been for some time manufactured in Germany, and works have been started in England for its production. Being a mechanical mixture of iron slag with slacked lime, it is very different in constitution from Portland Cement, which is a true chemical combination!!! Cement (Portland) adulterated with slag and slag cement, will be found finer ground and quicker setting than Portland Cement, and it will obtain its maximum strength at a shorter date than the best Portland Cement, etc., etc."

From the above it seems to me that all the differences mentioned as faults are rather in favor of the mixing of Portland cement with slag cement, or in favor of the use of pure slag cement.

The manufacture of cement from furnace slag is no longer an experiment but a fact, of which advantage should be taken in the United States. So far as I am informed, there is at present no manufacturing concern of this kind in the United States.

From reliable statistics I find that the imports of Portland cement into the United States in 1892 were 2,686,921 barrels. There is, as is well known, a large amount of Dusseldorf and Stettin cement brought into the United States yearly, so that a safe estimate of imported cements would probably bring up the total to 5,000,000 barrels per year.

In conclusion, I beg to quote from the *Progressive Age* of November, 1894:

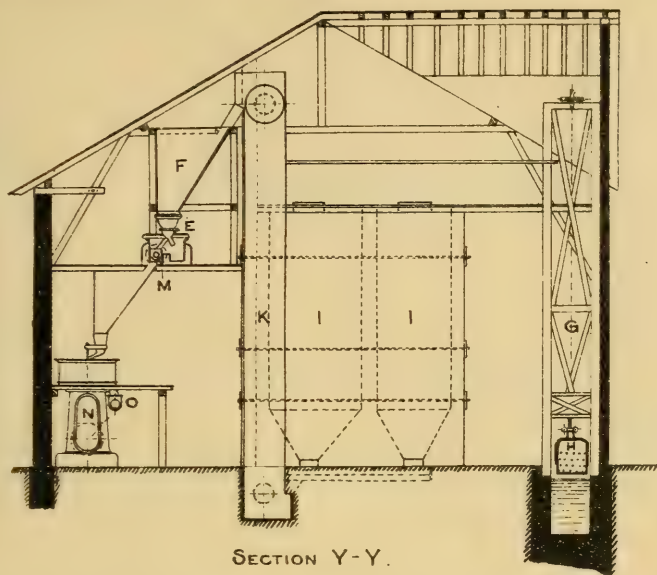
"*Portland Cements*.—We come now to a class of cements, says Ross F. Tucker, in the *Brick Builder*, which are so well known as to require little description. They are artificial cements, the product of scientific investigation, and the perfection of the principle underlying all cement hardening. By analysis and constant experiment the exact proportions of lime, silica and alumina necessary for the production of the most perfect union have been determined, and the mechanical processes for mixing, burning and grinding have been so perfected as to produce a

cement, the quality of which leaves nothing to be desired. They are, for all practical purposes, absolutely uniform in quality; they develop tremendous strength in concrete; they are economical, and may be used with large proportions of aggregates; they are invariable in color, and for hydraulic qualities have no rival. *The German Portlands are the finest in the world in all respects*, and an engineer may be at ease when his work is being done with these standard cements. The English Portlands are more variable, coarser ground and less economical. The process of manufacture differs widely in the two countries, and possibly the characteristics of the people of the two nations are shown in the results of their work.

"The Portland cements of American manufacture have a long road to travel before reaching the standard of excellence achieved by our rivals across the water; but with the great quantities of material suitable for this work at hand, it is only a question of time when American ingenuity will devote itself to the production of a domestic cement of equal quality with any in the world.

"The writer is not aware of the existence of a cement plant in the United States in which the production is carried on precisely as in Europe, nor is the term 'Portland' justly assumed by a great majority of American cements. It is doubtless true that several grades of domestic cement have attained a high standard and are suitable for use in important work, but they are few, and extraordinary care must be observed in their use, and every precaution taken to guard against the great bugbear—variation—for until that is absolutely overcome no cement can hope to take precedence of excellent products, which by long and successful use have proven themselves worthy of the highest regard, and which have won for themselves the first place in the confidence of professional builders."

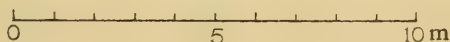
No doubt the German Portland cements here referred to are artificial cements, made principally from furnace slag and other mixtures, for, so far as I know, there are in Germany no natural cement stones from which cements could be made.

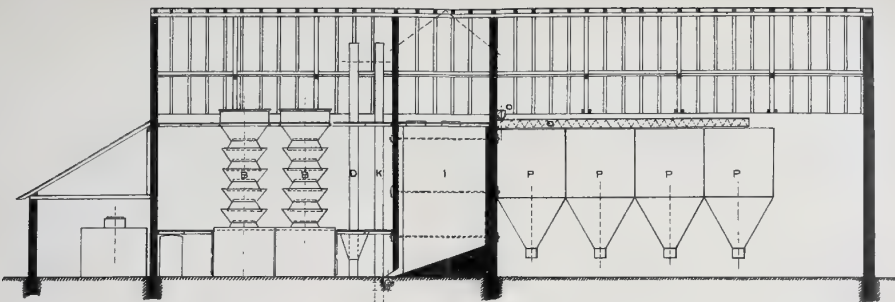


SECTION Y-Y.

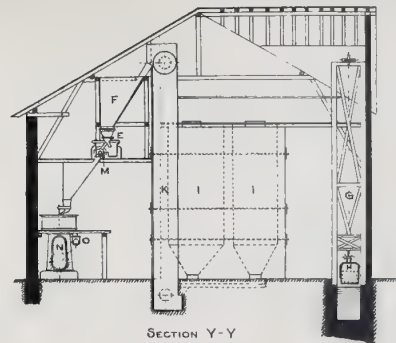
GENERAL PLAN
OF A
GERMAN FURNACE SLAG CEMENT FACTORY
AS DESIGNED BY
PFEIFFER BROS OF KAISERSLAUTERN

SCALE OF FEET

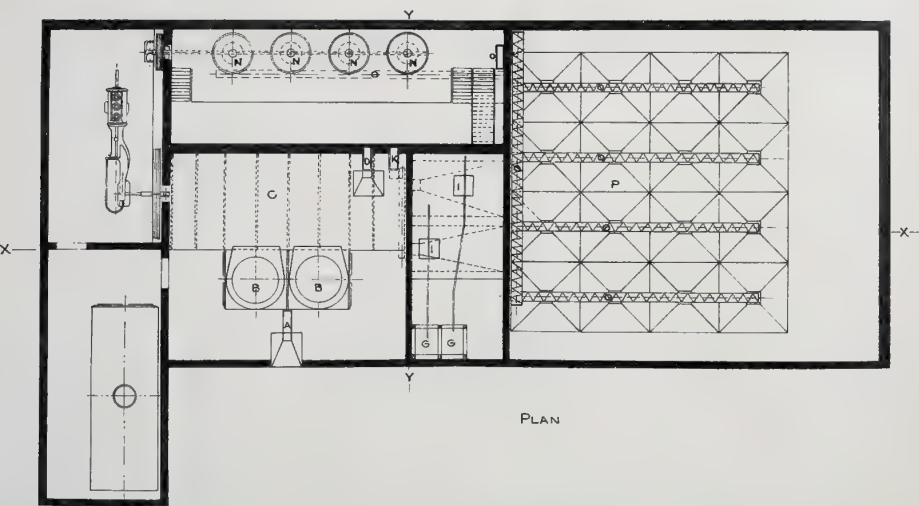




SECTION X-X



SECTION Y-Y



PLAN

GENERAL PLAN
OF A
GERMAN FURNACE SLAG CEMENT FACTORY
AS DESIGNED BY
PFEIFFER BROS OF KAISERSLAUTERN
SCALE OF FEET

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THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

The Technical Society of the Pacific Coast.

This society, the last of those recently admitted to the Association, is far from being the least. Organized in 1884, with a membership of 126 members, it numbered 219 members in 1892. Since then, owing to the business depression which has prevailed throughout the country, its numbers have been reduced until it now numbers about 170 members, of whom about 100 are resident in San Francisco.

This, however, appears to be one of those societies which should be estimated not by number but by weight. Representing, as it does, that remarkable section of our country where nature seems to have given occasion for the exercise of engineering effort upon the grandest scale and in a vast number of novel directions, its membership has always been made up largely of giants in the profession.

The first president of the society was Col. George H. Mendell, of the U. S. Engineer Corps, whose paper describing the use of concrete at Fort Point was printed in our JOURNAL for March. He was ably seconded in his official duties by the late George J. Specht, the first vice-president, who was one of the founders of the society, if not, indeed, its father.

The recent remarkable progress of the society is attributed to the activity and earnestness of Mr. John Richards, past president, a mechanical engineer of wide reputation and unusual skill, two papers from whose pen will appear in an early number of the JOURNAL. Mr. Richards' paper on Abrasive Processes in the Mechanic Arts, published in the Transactions of the Society for 1891, is regarded as one of the most interesting and valuable of the society's papers, and one which may justly be called classic. Mr. Richards is at the same time editor of *Industries*, a well-known magazine devoted to science, engineering and the mechanic arts.

The regular meetings of the society are held on the first Friday evening of each month.

The society's papers will now reach an audience many times greater than ever before, and it is confidently hoped that its influence will be even more widely recognized and appreciated.

The Engineers' Society of Western Pennsylvania.

This very important society is now considering the advisability of becoming a member of the Association of Engineering Societies.

In the JOURNAL for January, our Librarian, reviewing the January number of the proceedings of this society in which the cost of "printing and binding" for 1894 was given as \$1388.50, assumed that these figures covered simply the cost of issuing the proceedings, and instituted a comparison showing that their cost on this basis was \$3.94 per page as against \$3.26 for the JOURNAL of our Association.

Since then, however, he has learned from the secretary of the Western Pennsylvania Society that the sum named included a re-issuing of the proceedings to each member at the end of the year, the preparation of circulars and meeting notices, etc., etc., leaving only \$594.15 as the cost of publication of the ten monthly numbers issued during the year.

On this basis, the task of demonstrating the economy of co-operation, although still an easy matter, is, of course, materially less simple than before.

As stated in our January JOURNAL, the total number of pages of the society's proceedings, including advertisements, blanks, covers, etc., was 352, making the cost per page \$1.69, while the 1290 pages of our JOURNAL cost, for the corresponding items, \$3.26 per page, or nearly 100 per cent more.

The pages of the society's proceedings, however, excepting those devoted to advertisements and covers, are in small pica and average about 365 words each, whereas our papers are set in long primer and average about 513 words per page, while the nonpareil pages of our index last year contained 100 more. The 94 pages (not including advertisements) of our October JOURNAL, which is a fair example, averaged 524 words each.

Reducing the two publications to the same number of words per page, we have \$2.43 as the cost of a page of the Society proceedings, as against our \$3.26.

It must be borne in mind again, however, that our aggregate membership last year was nearly 1200, as against, say 450 for the Western Pennsylvania Society. Taking this into consideration, we find that with pages of equal size the cost per 100 member-pages to the Western Pennsylvania Society and to our Association were 54 cents and 27 cents respectively.

Or, reciprocally, assuming, for convenience, that all the pages of the two publications average respectively 524 and 365 words per page, we find that the 1290 pages of our JOURNAL, supplied to nearly 1200 members at a cost (covering corresponding items) of \$4,205, furnish over 192,000 member-words per dollar, while the 352 pages of the Society proceedings, supplied to, say 450 members, furnish less than 98,000 member-words per dollar.

It appears that the cost per member per annum to the Society in question is now, say \$1.32, whereas the cost to the members of the societies in the Association for the same items during last year was about \$3.50, or nearly three times as great; and in the case of a society which was barely holding its own financially this would of course be an important consideration, however desirable it might be to be furnished with over five times the amount of matter, at less than three times the cost; but to a society so eminently prosperous as the one we are considering, it would seem that this consideration should have but little weight.

It is needless to point out that the foregoing comparison takes into consideration merely the *mass* of material furnished, with no regard to its character or variety, and that however valuable the proceedings of any one society may be, it is of great importance to its members that they should have furnished them, in addition to their own papers, the results of the work of eleven other societies, including those of Boston, Chicago, Cleveland, St. Louis and San Francisco, especially when the union between these societies extends, as ours does now, from the Atlantic to the Pacific and from Virginia on the south to Montana on the north.

Canals Joining Lake Erie and the Ohio River.

Cincinnati and Pittsburg are active in the promotion of schemes for ship canals to connect their respective cities with Lake Erie, and thus with the St. Lawrence River and the ocean.

In February, 1894, Mr. M. D. Burke read, before the Engineers' Club of Cincinnati, a paper outlining the project for a ship canal from Cincinnati to Toledo, and setting forth its importance. The old Miami and Erie canal now connects the two cities, crossing a summit 393 feet above Lake Erie and 513 feet above low water in the Ohio at Cincinnati. It is believed that by introducing a system of slack-water navigation in the Miami and Maumee Rivers, emptying respectively into the Ohio and into the Lake, and by similarly improving the Licking River, which flows northward through Kentucky into the Ohio opposite Cincinnati, an outlet will be afforded for the soft coals of the eastern Kentucky fields.

Mr. Burke makes an earnest protest against the commonly accepted statement that canals, as transportation lines, have been superseded by the railroads. While this may be true in itself, Mr. Burke urges that the disadvantages under which the canals have labored should be taken into consideration.

The Pittsburgers are considering the construction of a canal from their city up the Ohio and Beaver Rivers to the junction of the Shenango and Mahoning, just below Newcastle. From this point two principal alternative routes are being considered, one via the Shenango reaching the lake at Conneaut, the other via the Mahoning to Geneva, near Ashtabula.

The provisional committee on engineering, consisting of five members, of whom Mr. Thomas P. Roberts, Chairman, and Messrs. W. L. Scaife and E. M. Bigelow are members of the Engineers' Society of Western Pennsylvania, have made a preliminary investigation of the country embracing these routes and have made a generally favorable report upon the project. The length of either route would be approximately 130 miles. The summit is 316 feet above the Ohio at Pittsburg and 443 feet above Lake Erie.

While it would of course be premature to make a close estimate of the cost without actual surveys, the committee submits a preliminary estimate making the total cost \$26,500,000, in round numbers.

Electrical Heating.

At a meeting of the Engineers' Club of Philadelphia on April 20th, Mr. J. Chester Wilson presented a paper upon this subject.

He referred to the use of the arc lamp by Cowles fifty years ago for obtaining heat in reducing aluminum. Electric flat-irons and glue-pots were shown, employing the incandescent principle, and various forms of street-car heaters using the same principle were described and illustrated.

In the discussion it was stated that the Niagara Construction Company offers to supply power in Buffalo at the rate of \$22.00 per horse-power per year, the power to be maintained constantly through the twenty-four hours.

Mr. Carl Hering referred to the electric heating of the Vaudeville Theatre in London, which, he understood, involved no increase in the expense.

In reply to the suggestion that while electric heating might do for trolley cars in temperate climates like that of Philadelphia, it would be found wanting in more northern cities, Mr. James Christie stated that in Canada he had found cars heated fairly comfortably while the thermometer was at 30° below zero.

Does Cast-Iron Expand or Contract at the Moment of Solidification?

The Collector had the good fortune to attend a meeting of the Engineers' Society of Western Pennsylvania on April 18th, when Mr. E. D. Estrada described a series of experiments he had made with the purpose of answering this question. Mr. Estrada referred to the experiments of Robert Mallett, described before the Royal Society in 1874, from which, finding that the specific gravity of the molten iron was less than that after solidification, he inferred that contraction took place in solidifying. In 1879 and 1880, Mr. Wrightson appeared to have demonstrated, before the Iron and Steel Institute of Great Britain, that the reverse of this was true, and that the iron increased in volume in the process of solidification.

Mr. Estrada placed a wrought-iron tube in the center of a flask and then surrounded the tube with molten iron. When the tube became red hot it was filled flush with liquid iron from a hand ladle. Immediately after the tube had been filled, the upper surface of the iron in it was chilled by means of waste previously soaked in cold water. Soon after this, molten iron began to ooze from the top of the tube, solidifying quite readily. From this and from other and nearly similar experiments with like results, Mr. Estrada arrived at an affirmative answer to the question proposed.

It was suggested, however, during the discussion, that the oozing out of the molten metal from the top of the tube might have been due, not to its own expansion, but to the contraction upon it of the tube containing it.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

The Washington Bridge.—The Library has received, with the compliments of the author and of Mr. Leo Von Rosenberg, publisher, New York, a copy of Mr. William R. Hutton's monumental work bearing the above title. It is so well and so favorably known to the profession that anything like a review of it at this day would scarcely be in order, but no apologies will be needed for expressing here our thanks for the compliment.

Meteorology. By Thomas Russell, U. S. Assistant Engineer. Macmillan & Co., New York and London, 1895. 8vo. \$4.00.

This book will be found convenient as a work of reference. The phenomena of weather are here defined, and what is known respecting them is ably and concisely stated. The degree of reliability of forecasting from various classes of phenomena is discussed. Thirty-five pages are devoted to instruments, their sources of error and corrections and proper exposure, and about fifty pages to weather maps and forecasting. Rivers, floods and river-stage predictions are fully treated. Twenty typical weather maps are reproduced, and sixty more show average depth and frequency of rain during days before and after the occurrence of such weather as is represented by each of the twenty typical maps. The maps are printed in three colors. The book, in its make-up, is a model of what such a work should be.

Asphaltum. NATURAL —, AND ITS COMPOUND. A paper prepared for the use of the professors and students of the Rensselaer Polytechnic Institute at the request of the Rensselaer Society of Engineers. By J. W. Howard, B.L., C.E., Troy, N. Y. 27 pages.

The author has set for himself the task of presenting in convenient form the facts which every one, or at least every engineer, must want to know about asphaltum and its various combinations, and he has used excellent judgment in his selections. The various forms under which asphaltum, or asphalt, appears, are defined, and their properties and principal localities are stated. The paper closes with a history of the development of the asphalt industry and a brief synopsis of its statistics.

Society Proceedings.

AMERICAN SOCIETY OF CIVIL ENGINEERS. *Transactions of the* —. Vol. XXXIII, No. 2, February, 1895.

This number is devoted to the presentation of a notable paper by Mr. William Hamilton Hall, describing the Santa Ana Canal of the Bear Valley Irrigation Co. in San Bernardino Co., Cal.

The main object of the canal is to take water from the Santa Ana River, reinforced, when necessary, during irrigation months, by waters drawn from the storage

reservoir within the river's watershed in the San Bernardino Mountains, and supply it for irrigation and domestic uses throughout some 45,000 acres of the northern portion of the San Jacinto Plateau or Valley. The work, like others in that remarkable country, calls for a number of operations of the most striking and picturesque character, including three pressure pipes of redwood staves bound with round steel rods, and working under heads of 150 feet or more. The work is very thoroughly illustrated, not only by scale drawings but by very striking photographic views.

FRANKLIN INSTITUTE. *Journal of the* ——. Philadelphia, April, 1895.

This number contains a paper, by Mr. Vaughan Merrick, describing and illustrating the City Avenue highway bridge over the Schuylkill River at Philadelphia. Mr. L. Y. Schermerhorn, President of the American Dredging Co., contributes a lecture on the Rise and Progress of River and Harbor Improvement in the United States.

The Institute, which has, almost from its beginning, occupied a small and utterly inadequate building in the older business portion of the city, is now making a determined and promising effort to place itself in quarters where it will have some opportunity of demonstrating its eminent usefulness, and the number before us contains a valuable historical and statistical sketch of the Institute and of its activities, prepared by the Secretary, Dr. William H. Wahl.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA. *Proceedings of the* ——. Vol. XI, No. 3. March, 1895.

The feature of this number is a valuable paper by Mr. Harry J. Lewis, on "Soft Steel for Bridges," accompanied by tables showing what is required of steel in various bridge specifications at the present time as compared with those of two years ago.

The tables show a marked progress in the recognition of the advantages of soft steel, and a decided movement in favor of the use of the open-hearth process. The paper was discussed at considerable length by Messrs. Emil Swensson, Max J. Becker, A. D. Wilkins and others, including the President, Mr. Thomas H. Johnson.

ALABAMA INDUSTRIAL AND SCIENTIFIC SOCIETY. *Proceedings of the* ——. Vol. II, No. 4, 1894.

By an awkward typographical error, the proceedings here given are set down as being those of December 14, 1895. The number contains papers on Spathite Iron, by M. C. Wilson; Dust-Catcher Refuse, by William B. Phillips; and The Formation of Cyanides in the Blast Furnace, by C. A. Meissner.

Spathite iron is said to be made only at Florence, Ala., and from an ore which comes only from Iron City, Tenn. The name seems to have been unfortunately chosen, inasmuch as the ore is not a true spathite, but a mixture of red hematite with carbonate of lime.



ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIV.

MAY, 1895.

No. 5.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

THE INDUSTRIAL PROBLEM OF THE PACIFIC COAST.

I. Address of the Retiring President,

MR. C. E. GRUNSKY.

[Read January 19, 1895.*]

IN giving way to your newly elected President, I desire to express my appreciation of the interest manifested at all times by the membership in the work of the Society, and to thank the individual members of the several Boards of Directors for faithful help and earnest endeavor to keep this a progressive organization, with a steadily increasing field of usefulness.

Our meetings have been well attended and there has been abundant material offered for discussion, through which we have been kept in touch with the progress being made on this coast in the practical application of science.

It is not my purpose at this time to attempt a review either of the several papers read before us, nor of the scientific, architectural or engineering work on this coast, but in view of the general depression of business, particularly in certain pursuits in which this State is interested, notably general farming, horticulture, viticulture and manufacturing, it may not be out of place to venture a conjecture as to the field in which further development will be most rapid on this coast.

* Manuscript received April 25, 1895.—*Secretary, Ass'n Eng. Socs.*

It must be apparent to every one that the low prices of manufactured articles as well as of products of the soil indicate general over-production.

It will take years before any great betterment of prices by reason of an adjustment of production to demand can be brought about, and this adjustment must mean either the abandonment of many of the less favored industries or a reduction of wages, unless means be found to increase consumption of products.

It is not therefore probable that our most rapid development of resources is to be sought in the direction of increasing products of speculative farming or of general manufactures, even though the lack of profit in speculative farming may compel the introduction of more diversified field crops.

The industry which bids fair to be stimulated directly by general business depression instead of suffering thereby, is mining, and particularly gold mining. The fall in price of raw materials, manufactures and wages means nothing else than a rise in the value of the metals used as mediums of exchange.

Preferred investments for capital will therefore be made in the direction of reopening such old mines as can now be profitably worked, new mines will be sought for and developed, and the field for such operations on this coast, and particularly in California, is exceptionally good.

But in suggesting possibilities of improvement in the mining industry, I do not wish to be understood as encouraging that portion of the business which is confined to the stock exchange, but mining as a legitimate business, which, in view of the almost virgin condition of the greater portion of the mineral fields on this coast, may be said to be still in its infancy.

Hand in hand with the development of the mining industry and as a factor in making such development possible, will come the utilization of power to be generated by the flow of our mountain streams. By electric transmission it can be delivered at those points where it will be of greatest service in reducing cost of manufactures, it will enable and encourage the establishment of industries which, without it, would have been impossible.

In these two directions, mining and power development, combined with electrical transmission, and in the general tendency which seems manifest throughout this coast for municipalities to have their own water and light works, the engineer sees a ray of hope for increased demand for professional services.

And now a word about the general business depression. Over-production is only another name for a lack of consumers of our products,

and it is clearly evident that a reduction in the cost of production is not the most desirable remedy with which to correct the prevailing low prices. This reduction would mean either a reduction of wages of labor directly employed in production, or reduction of the expense of marketing the product, consequent upon which there must follow reduction of wages of the employees of transportation companies and of merchants.

Permanent relief then should be sought in another direction, in the direction of increasing the number of consumers, though not necessarily by seeking new markets. It is well known that the method of increasing consumption by bringing this country into direct competition with countries where low wages are the rule, can have but one result—the gradual but inevitable reduction of wages to the lowest standard, determined on the basis of nearness to foreign markets, coupled with the infliction of injury upon the industries of other countries, or, possibly, other sections of our own country. The increase of consumers should rather be secured by increasing the proportion of population engaged in non-producing pursuits.

Assume for a moment that our present system of indirect taxation be completely abolished, except in so far as made necessary for the protection of manufacturing industries, and all revenue for the support of Government be secured by a system of direct and equitable taxation, and that under intelligent and judicious direction large sums of money be expended in the execution of public works, and for purposes of scientific research, and in the interest of education, the result would be that all the money thus expended would be put into the hands of non-producers; it would come into circulation through the best possible channels; it would be paid out principally for labor, and through the laborer it would find its way to the butcher, the baker, the manufacturer of clothing, of shoes, of hats, and through these again to other dealers and agents and laborers innumerable, yet all consumers of each others' products and all jointly interested in maintaining a large and rapid circulation of money, a great volume of exchange of products.

The time will come when we must depend almost exclusively upon a home market for our products, and all legislation, all agreements with foreign powers, should be shaped with this fact in view. To have something to sell to our neighbors is certainly desirable, but to have to abandon the fertile wheat fields of our great central valley, the fruit farms of our coast counties and foothill regions, the vineyards of Sonoma and Fresno, the orange groves of central and southern portions of the State, merely because the market beyond the limit of the United States is closed to our product, would certainly be a calamity, and it is well to be prepared to avert this calamity.

There are now annually expended by the United States for river

and harbor improvements about \$20,000,000. This money is expended for salaries, general expenses and, through contractors, for labor. All of those depending upon the expenditure of this money for a livelihood, again expend practically all of it for necessities and comforts of life. In the form of profit it becomes a factor in building up the wealth of individuals.

But if money be taken by equitable taxation from those who have by accident or natural qualification been placed in a position to accumulate beyond their immediate personal needs and desires, then the more that be taken and put into circulation through such channels as the construction of public works, the greater must be the general prosperity of the nation. This remains true entirely independent of the aggregate amount of money in actual circulation.

Suppose for a moment that the business of the country, national, state, municipal and individual were conducted on the basis of a rapid instead of a slow circulation of the medium of exchange, it would give the money-getter increased opportunities, fully equal to the increased taxation necessary to accomplish this; it would increase the opportunity for earning a livelihood by physical and mental effort; it would stimulate varied production by the agriculturalist with a tendency to less speculative farming; it would have the best possible effect on the advancement of civilization, the betterment of the human race; it would engender permanency of our industrial conditions.

It has always been the policy of our government, national and local, when times are hard, and business is depressed, to reduce taxation, to curtail expense, to cut down salaries, to enforce the gradual degradation instead of the elevation of the nation. This policy is wrong, yet it must be admitted that there has been some excuse for it. Under our system of indirect or unequal taxation, supplemented by fraudulent assessment, the sudden reversal of this policy would for a time at least bear too heavily upon the very best element of our commonwealth, upon the citizen whose entire savings are represented by the home which shelters his family and which is always taxed proportionately far in excess of large holdings and of property not as tangible as real estate.

But let direct taxation for national purposes be once introduced, as it could be without material expense in the matter of collection of taxes, and it will not be long before means will be found to secure from the wealthy their full quota.

Self-interest should prompt every citizen of the United States to favor such a policy as here briefly indicated.

The opportunities for judicious great increase of expenditures in so far as the general government is concerned, will readily suggest themselves.

Public works, such as river and harbor improvements, coast defenses, the construction of war vessels, the maintenance of an efficient navy and army, the maintenance of bureaus for research: agricultural, geological, astronomical, orographic, hydrographic, hydrometric, meteorological; the construction of public roads, canals, railroads, the liberal support of institutions of learning, and for the study and encouragement of the fine arts, are but a few of the many.

Such a policy would by no means impoverish the nation, no matter what limit be set for the annual expenditure, provided that due consideration be always given to the necessity of keeping the money expended, at home; a circulation of money must be established similar to the circulation of the blood in the human body. Government may be likened to the human heart. By an equitable system of taxation it should cause a steady flow of money toward its coffers, and by honest expenditure for purposes as above indicated, a healthy return flow should be maintained, which would be felt to the limits of the land.

To some extent this policy prevails abroad. Look at France, at England, at Russia, at Germany, and consider for a moment the enormous expense entailed by the maintenance of armies and navies. The question may well be asked: is such maintenance a burden? and there can be but one answer. The expense of maintaining armies will never bankrupt any nation of varied resources so long as it be maintained by home products. This expense may be likened to the fly-wheel of the steam engine, it keeps the affairs of the people in smooth grooves. The host of people supported at national expense as non-producers, affords the market for the products of the reduced number of producers. The taxation for the maintenance of the army is not oppressive, so long as that very army enables the producer to make a profit, which would otherwise be out of his reach. But in our own case it is not necessary to maintain a numerous army in order to increase the proportion of non-producing population, it can be done in much more useful directions as already suggested.

It appears, therefore, that all money expended by the nation for useful, ennobling work, should not be considered a national expense at all. The money thus expended not only serves as an agent to create public buildings, works of art or a good war vessel, as the case may be, but by supporting non-producers it is of direct benefit to every producer and wage earner in the country, and every time it is withdrawn from those who are hoarding it and is sent forth again for distribution to those who have been less fortunate in making their labor profitable, it repeats its good work.

Without any attempt to elaborate this idea it does appear that the prosperity of the country should not be measured by the money in circu-

lation, but that it is rather the product of the amount by the rate at which it is made to circulate, and that every well-regulated country has it in its power to control the rate of circulation, by equitable taxation and liberal, well-distributed expenditures.

THE INDUSTRIAL PROBLEM OF THE PACIFIC COAST.

II. Inaugural Address of the President,

MR. GEORGE W. DICKIE.

[Read January 19, 1895.*]

Members and associates of the Technical Society of the Pacific Coast:

I consider it an honor to be selected by you to preside over the destinies of this Society for the coming year, although you may not be doing yourselves an honor by such a selection.

I am afraid that my only qualification for this office is an earnest desire to see this Society realize the hopes of its warmest friends. If this desire of mine could only be combined with the wisdom required to bring about the realization of these hopes, we would begin to-night to make progress towards a wider field of usefulness than we have hitherto occupied. It is, therefore, to be hoped that your board of directors will be able to supply my lack of wisdom, and thus realize your brightest hopes.

Finding myself in the position that demands that I should address you to-night on some subject that would in some way touch on the many and important interests represented by the members of this Society, I began to bethink me how I could best meet that demand. It is the usual custom for such addresses to take the form of a review, showing the progress made during the year past, in the sciences or industries representing the work in which the Society's members are engaged; but, in looking over the past year for some inspiration from the application of science to the advancement of the industries of the Pacific Coast, I have found little to encourage me to make that alone the theme of my discourse.

It will profit us nothing to go on discussing the technical details of engineering or chemical science in its application to any of the industries now existing or likely to be established in our State, if such industries are not surrounded by conditions favorable to their existence. What would we think of a doctor who, when called upon to resuscitate a drowned person, should begin to doctor up the external injuries, rubbing

* Manuscript received April 25, 1895.—*Secretary, Ass'n Eng. Socs.*

liniment on a bruise here, and binding up a wound there, instead of devoting his whole attention to getting the breathing and circulating organs to perform their proper functions?

The immediate duty of this Society, and of all similar organizations that come into touch with the material interests of this State, is to help, by every means in their power, in the creation of a sound, vigorous and patriotic sentiment in regard to the development and expansion of every interest that naturally should live and thrive amongst us.

The time and conditions are upon us when we must, for a time at least, give up the discussion of small questions of technical detail, and join in a grand and general movement for the revival and extension of the industrial and commercial interests of the Pacific Coast. Joining in such a movement may not be quite in keeping with the proper functions of this Society, but when the existence of our industries, and with them the extension of our commerce, is in danger, the discussion of technical matters of detail relative to any branch of either of them is simply an evidence that those interested are too busy with their own individual concerns to pay any attention to the general problems that at present confront us.

The exact method or manner in which we are to work is not the main question with those of us who have been struggling to establish industries in this State, but whether we are to have the chance to work at all, is the question of to-day with which we stand face to face. This is not an industrial or a technical question; it is a community question, and an affirmative answer must be the result of laying aside individual selfishness and fostering of enterprises, the prosecution of which tend to the development of our material interests as a community.

I am fully alive to the difficulty of bringing about anything like a unity of sentiment in a community like ours, built up of material from all parts of the earth, whose habits of thought and methods of work are as widely apart as the places from whence they came. And yet, this very thing must be brought about before our commercial or industrial enterprises can become prosperous or enduring.

As an illustration of how the particular method of doing a thing will often become the subject of discussion, instead of the vital question as to whether the thing should be done at all or not, I will give the following from a paper of mine read before the last meeting of the Society of Naval Architects and Marine Engineers in New York:

"There is a grand opportunity for the establishment of a great American steamship line in the trade between San Francisco and New New York via the Straits, taking in the principal seaports of the South American Continent. We believe that a business could be built up to admit of two steamers per month, having a general freight capacity of

6,000 tons each. These vessels should have speed enough to insure 65-day trips, and should have first-class accommodations for a limited number of cabin passengers between way ports. They should have cold storage compartments, and such a subdivision of cargo space as would permit of a varied assortment of general products being carried. They should be designed so that in case of need the Government could use them for cruiser transports. They might also be partly or altogether manned by a naval reserve force, and thus form an excellent base of supply for the Navy. Such a line would open up great possibilities, both to our merchants and producers, and eventually would give us South America for a customer. In order to make such a line a success the ships must be first-class in every detail and especially designed for the work. They must have regular sailing days, not too far apart, and, in order to provide for these essentials, Government aid would be necessary for a number of years. This might be in the form of a mail subsidy, or a mileage rate, but should be liberal enough to insure a high-class service. The money thus spent would be as nothing compared to the benefits that would result to the trade of the country, especially that of California."

Quite a number of Eastern technical papers have been, since the reading of this paper, discussing that part of it just quoted, but not with the view of stirring up a sentiment favorable to this and kindred enterprises, having for their object the extension of our commerce; but first one and then another has devoted its space, and drawn the attention of its readers from the main question, by discussing the technical details of the plans by which I propose to carry out such an enterprise. One said, "Your ship must have twin screws and no masts." Another said, "You must have tramp steamers of the cheapest type, there being no need of carrying passengers," and another said, "There was no need for cultivating South American trade, and therefore no need to stop at way ports," while still another claimed that it would be wrong for the Government to help an enterprise when California was to receive the benefit.

Now, my object was not to advocate this, that or the other kind of tool for doing the work, but to point out the necessity for the work being done, and to bring about in the minds of those best able to carry out such an undertaking, the determination to join forces and do it.

Our mercantile houses and manufacturing establishments are suffering from atrophy, which, if not arrested, will result in a gradual extinction of all enterprise. This process is now going on, and the sad part of it is that as first one and then another enterprise has to be abandoned, others seem to think that the closing out of their neighbor and competitor will in some mysterious way be an advantage to their business.

This selfish indifference to the general condition of the trade or indus-

try in which the individual may be engaged or interested as long as his own particular business survives, is the principal obstacle standing in the way of a general revival of industry and commerce in our State.

The general apathy so prevalent, and which is so fatal to all our material interests, must be dispelled before any revival of trade can be expected.

There should be an understanding amongst ourselves as to what industries naturally belong to this State, and these should be fostered and protected. Wise legislation is required in order to encourage the establishment amongst us of such industries as the natural products of the State would warrant us in believing would cause to become strong and prosperous.

Public burdens should, as far as possible, be removed from industrial enterprises, the prosecution of which requires the employment of great numbers of skilled and unskilled people.

It is such establishments that create values that in time become the foundations of all public revenue, and to weaken or destroy the source from which these values spring, is to kill the goose that lays the golden egg.

The great question of transportation has, during the past two or three years, kept our merchants and producers in a continual state of excitement without any permanent satisfactory result. The reason of this unsatisfactory result is the same want of unity of aim and action on the part of those interested, greatly aggravated by a stupid fight against what are called the exactions of the Southern Pacific Company. This company, with all its allied interests, in my opinion, is the only thing of life in our State to-day, and if it owes its vitality and power to the subjugation of all other interests, it has simply succeeded in doing what every business man tries to do, and its success, like all other successes of the same character, is not so much owing to the superior skill and enterprise of its managers, although that is no doubt of a high character, but largely to the want of enterprise and united action on the part of those who are loudest in their complaints against the power that holds them in subjection. Naturally, California is well fitted to be a great commercial and manufacturing state, with a climate well adapted to the prosecution of every kind of manufacture. With a soil that richly repays the labor bestowed upon it, and set right in the centre of its great coast line, one of the finest harbors of the world, why should we not take a better position than we do now in the manufacturing industries of this country, and in the commerce of the world? Our merchants, most of whom came here from the Eastern States to open branches of houses established there, have kept on doing business with their faces turned toward the East; have built their business houses with their fronts facing

in the same direction, and standing in their front doors, wondering what has become of their business. They can see nothing but the railroad, with the towns along its route getting their supplies from the west-bound trains, because they happen to be at the far end of it.

Now, if these merchants would just turn their business houses around so as to face the other way, they would be at the beginning of the railroad instead of being at the end of it, and loaded trains would leave their back doors, instead of empty cars standing at their front doors, and the railroad would do just as well hauling east as hauling west.

It is not necessary here to point out the means by which this change is to be accomplished. I have already done this, as far as the matters on which I have any knowledge are concerned; but my proposals have hitherto been in advance of any desire on the part of our merchants to profit by them.

To-night I desire to enlist all the members of this Society and all those whom they can influence in a united effort, to help revive the manufacturing industries of this State, and the commerce of San Francisco. Every influence has an effect, and we can all do something in this direction. Consulting Engineers should advise their clients in regard to favoring the products of our establishments. Nothing but an inability to produce the article required should be an excuse for its being made elsewhere. We can never be prosperous until we supply a larger percentage of our requirements from the results of our own labor. A large portion of the youth of our State are now growing up in a condition of enforced idleness, which adds to the already heavy burden of the few who have the opportunity to work. We are opening schools for manual training in the mechanical arts, and at the same time closing our workshops. What good will come of teaching trades in our schools and not fostering the practical application of such knowledge in our industries? There is a young generation, to say nothing of their fathers, begging at our shop doors to-day for the opportunity to earn a living at their trade; but the industrial wheels are either stopped or moving so slowly that there is no chance for them to work, and this in a young State with vast resources undeveloped, and which, from her position, should control the trade of the Pacific.

The Technical Society may not be able to accomplish very much in the direction herein indicated directly, but such societies have an immense power indirectly. Our members are being constantly brought into contact with business men representing large interests, and their advice and opinion very often goes much further than the party giving it is aware of. Let our influence be exerted continuously in the one direction of helping by every means in our power the growth and development of our home industries. Well-directed efforts patiently

kept up by technical men will ultimately result in the formation of a sentiment that will pervade the whole community, making legislation in the right direction possible, and when once our people understand the possibilities latent in the resources of this great State, there will be an awakening of dormant industries. Our merchants will find new markets for the products of our skill, and instead of driving labor from the closed doors of our factories, we will be inviting the idle hands of other States to help us meet the wants of customers in every land that looks on the Pacific.

THE RELATION OF RAILROAD TRANSPORTATION TO PRODUCTION IN CALIFORNIA.

BY R. L. DUNN, CIVIL ENGINEER.*

[Read September 7, 1894.†]

IN the Sacramento *Record-Union* of March 11, 1892, appeared a paper entitled "California Landholdings," written by Mr. W. H. Mills, who is a prominent official of the Southern Pacific Company. Though in it there is no reference to railroads or to railroad transportation in California, singularly enough, and probably unintentionally, it is specially of value as it throws light on railroads and railroad transportation in California. Surprisingly, because written by a Southern Pacific official, it is the most complete and correct statement of the results of the Southern Pacific Company's business policy that has yet appeared in print, and more conclusive and impressive in this year of 1894 than when written in 1892.

It is only fair to state that the writer seems to have been utterly unconscious of a possible significance of his elaborately gathered facts and statistics other than that presented by him. That they have a definite relation to the Southern Pacific Company's rates of fare and freight, is recognized by Colonel R. S. Morgan in his report to the Railroad Commissioners, Messrs. Beckman, Rea and Litchfield, in 1892, in which report he embodies a portion of Mr. Mills' paper as an exhibit,

* Before reading his paper Mr. Dunn said :

Some two years since, in connection with my profession as a civil engineer, I was engaged in investigating the irrigation problem in Placer County, Cal., and I wanted to demonstrate, to men who had lands that could be cultivated, the desirability of irrigation. I examined the assessment rolls of the county to ascertain the difference between the value of lands that were irrigated and of those that were not. In making this examination I came across a number of other things of interest on the records, from which I made several tables. Just about that time William H. Mills, of the Southern Pacific Company, read a paper before the Chit Chat Club of this city, entitled "Large California Landholdings." This was printed in the *Sacramento Record-Union*, and afterwards in pamphlet form, and circulated all through this State. It happened that it was precisely the point that I had been investigating, and as the result of reading that, and as the result of my investigations, I prepared this paper. I have remodeled it somewhat, so as to bring it a little closer to the times and the date, and have entitled it, not "Landholdings in California," but "The Relation of Railroad Transportation to Production in California."

† Copy received April 25, 1895.—*Secretary, Ass'n of Eng. Socs.*

and in his argument uses the facts it states as a reason why the rates of fare and freight should not be reduced, but must be maintained.

Mr. Mills in his paper, by compilations of statistical figures taken from the census of population, shows a decrease in population of certain of the agricultural sections of the State, and by another set of statistical figures taken from the county assessment rolls, establishes as the cause of this decrease of population, the increase of large landholdings through the consolidation of small landholdings. Had the statistical figures of the freight and passenger traffic of the Southern Pacific Company for the same time and territory been given, the paper would have had the value of completeness as well as correctness. Apparently, however, Mr. Mills if he had these last statistics in mind at all in preparing his paper, considered them only as expressing one of the unfortunate effects of the decrease of population and of the increase of the monopoly of the land, and therefore not relevant, either to the consideration of the cause of that decrease of population and increase of land monopoly, or to the remedies desirably to be applied.

Mr. Mills states as a conclusion from his statistical figures and general argument, that the land monopoly developing in California is in the highest degree prejudicial to the best interests of society and the State, in that it is not only decreasing population and wealth, but is sapping at the very foundations of our political institutions. Realizing the necessity of society and the State destroying land monopoly before land monopoly destroys society and the State, he proposes certain legislation as the justifiable and desirable corrective to be applied. Considering the cause of land monopoly in California to be the rapid accumulation of wealth, that seeks investment in land largely for the security alone, and the facility with which land can be made the pledge for borrowed money, his proposed legislation would make: first, the use of land as security for debt practically impossible; second, the future accumulation of wealth in land illegal; and third, would force the distribution of land already so accumulated by prohibiting its succession by will. Questioning all of this proposed legislation, I realize that a discussion of it is profitless except as the statement of fact on which it is based is correct.

Is the cause of land monopoly in California what Mr. Mills states it is, or is there some other cause? Or, stating the question in another form, are Col. Morgan and the Railroad Commissioners right in saying that the decreasing population and increasing land monopoly justify the rates of freight and fare imposed by the Southern Pacific Company, or are they wrong? Are decreasing population and increasing land monopoly the causes of the condition of fares and freights, or is not the fact that the condition of fares and freights is the cause of decreasing population and increasing land monopoly?

Mr. Mills emphasizes the undesirable social condition forced on the small landholder as being the cause that eventually displaces him to increase the monopoly of the land. This small landholder, he very truly says, is deprived of opportunities of education and society for himself and his children, and must live a socially unpleasant, isolated life. This social condition, however, is itself an effect of the real underlying cause, which is the undesirable business condition of his small landholding. It does not pay. And it is because small landholding has become more and more unprofitable that it has become undesirable and has been given up, schools and churches disappearing with it. Anywhere in the State where small landholders are engaged in general farming and the production of the staples the same story will be told. Farming does not pay, and the small landholder is anxious to sell. For this condition of not paying there are several causes, some generally known and recognized, and others not. There is no question but that the great plains of the Sacramento and San Joaquin Valley no longer yield as much wheat to the acre as fifteen years since, and their production of wool, hide and meat is less in even greater ratio. There is no longer a relatively large local market of people who are not producers of agricultural commodities, the mining communities of this State and Nevada, and the local market that remains is partially supplied with the surplus of outside points of production. All staple agricultural products are lower in sale value in the outside markets of the world through the competition of cheaper areas of production. General business conditions have so changed that, quality being the same, the large producer has invariably the advantage of the market over the small producer. Where the small producer has to accept in transportation the general tariff of the railroad, the large producer can frequently get special rates. Car, storage and shipping facilities are given to the large producers, that the small one must pay for and sometimes cannot get by paying for. The difference of rates between carloads and fractional carloads is to the constant business disadvantage of the small producer. The large producer gets free transportation frequently, the small one never. Most serious of all, the rates of transportation for the distinctively small farm products, butter, eggs, poultry, vegetables and fruit, which bring higher prices per unit than the staples, are such that, so far as the producer is concerned, they are no more profitable. The extent and value of farm improvements, averaged to the acre of farm, are, as a rule, inversely proportional to the total of the acreage. Small farms have several times the amount to the acre that the large farms have. Personal property appurtenant to the farms has the same acre relation. The acre of the small farm is thus burdened with a heavier flat investment than the acre of the large farm, and is taxed annually on that excess of burden.

The direct tax on land determined by its acre assessment can be made, and is more often than otherwise made to favor the large landholder. Each acre of the small landholding has absolutely a larger burden of capitation taxes, poll, than the acre of the large landholding, and absolutely a larger voluntary tax for the support of churches and semi-public institutions, and for fees and charges to public officers. The direct farm cost of production of staples is less per unit on a large landholding than on a small one, simply because the labor is cheaper.

No one of the preceding differences is very many dollars in itself, or very many cents in acre charge, but the aggregate of them all is large. It is distinctly to the disadvantage of the small landholder. Comparing the acre cost of production, taking all these items into account, there is a much smaller margin of acre profit for the small landholding than for the large landholding. And it is possible for a depression of sale values permanently, or for a temporary fluctuation even, to wipe out entirely the margin of acre profit for the small landholding, and still leave a margin of acre profit for the large landholding. This, in fact, is exactly what has been happening during the last fifteen years. The margin of profit for the acre in small landholdings has become entirely wiped out or so nearly so that the farming of small landholdings has become surely unprofitable, and as a logical and business necessity they have become undesirable. The margin of profit for the acre of large landholdings has been materially cut down, but the large landholders have maintained, or tried to maintain, their aggregate net income by increasing the number of acres from which to draw it.

It is this last tendency that Mr. Mills has observed in the statistics, and which, utterly out of touch with the men who own and work, he calls the desire to own land for its security as an investment and as a basis for loans. In reality the tendency is the expression of the instinct of self-preservation, the desire to survive by the line of least resistance against conditions becoming more and more adverse. That this tendency persists is due to the fact that the larger landholdings have or have had surplus incomes that can be applied to increase acreage even when the small farm becomes unprofitable. The small farm, unprofitable by itself, becomes profitable as part of the large farm simply because the load of its occupancy by the small landholder is taken off.

The primary incentive to the acquirement of wild land is the anticipation of profit through a rise in value, this rise in value being what is termed the unearned increment. It is the increase due to the development or anticipated development of the earning power in excess of current interest on the primary investment, being the capitalization of

that excess of income at current interest. In farming lands the amount of this increase is of necessity dependent on the character of culture and improvement possible and on location with reference to centres of trade and population and channels of communication. Soil and climate determine the most desirable kind of product for the land, and on its mean annual profit is established its basis of value. Here in California the product has been wheat. An examination of land values anywhere in the wheat-growing sections will show them based almost exclusively on the acre product of wheat, and, except in isolated districts, entirely independent of the cost of transportation or distance from centres of trade and population. The values thus determined twenty and more years ago have been fairly constant as the rate of current interest has been steadily decreasing, and as fluctuations in the sale value of wheat were practically compensated to the producer by the flexibility of the freight rates to the markets of Europe. The primary purchase price per acre being very small, wheat productions gave incomes that were interest on sums several times the flat investment. It was not uncommon for the first crop to pay back the cost of land and of all the improvements.

The minor farm products having the local market free from the competition of the surplus production of the East were also very profitable. The limit of value for these lands was rapidly reached, and for many years past their desirability came to depend wholly on the amount and certainty of their net income-producing power. This, however, instead of remaining constant, has decreased so much that the consolidation of the small farms with the adjacent large ones has been forced. The decreasing current interest rate, by maintaining the exchange value of the land, has operated to conceal the cause. So, too, has the anticipation of the development of an increased earning power through a change of production. The business results of farm culture during 1893 and 1894 have swept away illusions, and the cause of our permanent industrial and business depression is clearly in evidence. Land monopoly and decreasing population are simply effects, the ultimate and worst effects, of the cause of that industrial and business depression.

It is people who make a country. It is the possibility and profit of production that attracts people. That kind of production which attracts and supports the largest number of people is the most desirable. Wealth is the net gain of production over consumption, established into relatively imperishable, but convertible, products or natural things. No kind of production which will not give a net gain over its consumption, which will not produce wealth, will attract people. It will not make a country. Mr. Mills' paper on "Large Landholdings" is the first published recognition by any official of the Southern Pacific Company, that

the net gain of production over its consumption is disappearing for California producers; that their lands under present conditions are not wealth-creating; that they no longer attract people; that, in fact, people are leaving them.

Mr. Mills finds population decreasing, and with it the acre production of the land. He finds acre railroad earnings are decreasing, and has made a partial discovery of the relation between population, acre production, and acre railroad earnings. In a published letter to Mr. Huntington he makes public the fact that wheat gives only a sixth of a ton of freight to the acre, and a short haul at a low rate; whereas fruit, another product of the soil, gives a carload of freight to the acre, and a long haul at a high rate. Though he does not state it, it is an obvious conclusion that the exchange commodities for these products have a like ratio of earning to the railroad, and with passenger traffic the ratio is even greater.

Mr. Mills clearly sees that conditions so disastrous to the best interests of society and the well-being of the State—and to the railroad—must be changed. He clearly sees that more people and smaller landholdings will accomplish the desired change.

As a means of getting more people in the country, and inducing them to cultivate the soil, the simple cutting-up and sale of the large landholdings is no inducement, and cannot be a success. As a matter of fact, the small tracts can be had now, but the desire to get them does not exist to any marked degree. Small landholding must first be made safely profitable before it can be considered desirable. To be made safely profitable the economy of production must be changed in the direction of materially cheaper cost to the producer.

The sale value of our great staple, wheat, is not determined by the production of California, but by the demand in Liverpool, and the sale value is fixed there. The sale value at the point of export in California, tide water in the Bay of San Francisco, is the Liverpool value less freight, interest and insurance. It is with this sale value at point of export that the California producer is concerned, and with the items and amount of the cost of production to that point. These items of cost of production are, first, the farm cost, which, on the authority of the State Board of Agriculture, is half a cent a pound under conditions of large acre yield on the very largest landholdings, and which is certainly three-fourths of a cent under the average conditions of acre yield and area of land ownership; and second, the freight and incidental charges of transportation.

The first of these items, the farm cost, cannot be lessened; if anything, economy has gone too far in the attempt. If the cost of production is to be lessened, it must be in the second item, the freight, more

specifically the railroad freight, wherever the railroad is a carrier. As sale values are at the present time, the railroad freight takes a portion amounting to a third, and more from wheat produced in the upper San Joaquin Valley. So much, in fact, that the sale value does not even recoup to the producer his farm cost alone, and for the use of the land it pays nothing. If small landholding is to be made safely profitable, small farm products must have the advantage in the local markets, which their nearness legitimately entitles them to. This advantage can be assured if transportation charges be made on the basis of the service rendered only. The present condition is such that the Eastern producer is admitted to the market on more favorable terms as to freight charges than the local producer. If small landholding is to be made safely profitable, railroad transportation charges must not discriminate between classes of production. Also, must the transportation of products, as between large and small producers, be placed on an exact equality? Finally, such transportation rates should be made on the distinctively small landholding products exported from the State as to insure a profit to the producer, despite the ordinary fluctuations and uncertainties of the market. To illustrate this last, take the case of a 25-pound box of green peaches (of Placer County), a distinctively small farm product. The cost of production to the point of consumption is made up of the following items:

1. The farm cost, cultivation, pruning, picking fruit, packing, and transportation to the railroad station	\$0.135
2. Water for irrigation . . . . .	.01
3. Box.. . . .	.07
4. Paper for wrapping.. . . .	.01
5. Putting into car . . . . .	.025
6. Railroad freight, including ventilator car (if with refrigerator car \$0.156 additional) . . . . .	.47
7. Selling commission, 7 per cent. . . . .	.05

Total cost of production at consuming point \$0.77

That is, the box of peaches must sell for 77 cents to just repay all the cost of production. If more than 77 cents is received, 93 per cent. of the extra amount is profit, which is the earning of the capital invested in the land and trees. This extra amount is now so small that a slight depression in the market sale value, or a slight impairment of quality incident to the long transportation, makes the fruit produce a loss to the grower. A margin over the cost of production of 15 cents (which is more than the average for the last two years) on a production of 500 boxes to the acre for 10 acres, amounts to \$750. In addition to this, \$0.135 a box, \$675 for 10 acres, the farm cost of production, comes back in the sales return. Of this last amount \$150 will be the cost of

keeping a horse, and \$250 wages and board of extra labor, picking and packing, leaving \$275 for the wages of the owner. This, added to the \$750, makes a total net return to the grower of \$1,025 per annum.

The same mechanical skill and intelligence required for the successful growing of fruit would bring to its possessor as wages, without capital investment, in other forms of industry, not less than \$3 a day, amounting to \$900 per annum. The difference between this amount and \$1,025, \$125 is, in reality, the total gross income of his capital of land and trees, from which must still be deducted taxes and other charges incident to the possession of property, leaving certainly not more than \$100 as the net income of his investment of 10 acres of land and orchard. The ultimate valuation of that land and improvements per acre, based on this amount of net income, money being worth 10 per cent., is only \$100, which just balances the actual cost of the trees brought to bearing, and leaves nothing to represent the value of the land. Of course the income of \$1,025 is, with other things, an inducement for labor, but it is absolutely none for the investment of capital in ten-acre landholdings.

As a fact, in this year of 1894, the profit margin is practically wiped out, and growers will be fortunate who realize sufficient to repay the farm cost of production. Undesirable as is this present condition, the outlook for the future is even more unpromising. The inevitable increase in production of fruit must find an increase in consumption to absorb it. This means a market among classes of people that the fruit does not now reach, and to be taken by them the mean sale value must be lower for the whole production to meet their ability to pay.

The future sale value is then certainly less than the present one, just as the present sale value is less than that of five years ago. This inevitable decrease in sale value can be compensated for and the margin for profit increased in only one way. The cost of production must be reduced, and in absolute amount a considerable sum. An examination of the several items of the cost of production given for the box of peaches will show only one large enough in amount, the freight, to be materially reduced. This, as it now stands, is 61 per cent. of the total, where the highest other single item, the box, is only 9 per cent. It is clearly evident that unless the freight item of cost be materially reduced, small landholdings producing fruit cannot be made safely profitable, and those that now exist will be absorbed by the larger landholdings.

The peach has been taken as the extreme favorable case for the small landholder. It is the peach that by the profits of its production a few years since has developed the unearned increment of Northern California lands, just as it has been the orange that has done a like service for the Southern California lands. It has been the development

of this unearned increment by the profits of the first in the industry which has made small landholdings desirable. In amount this unearned increment has exceeded many times the basis value of the wild land, or the land used for staple production.

Take Placer County, concerning which I am best advised as to the facts, for an example. In it, in 1891, there were just 6,000 acres of irrigated land in about three-fourths of its maximum possible production, that is, it was not all in full bearing. The figures taken from the assessment roll show an appreciation in value, such a development of the unearned increment as to seem hardly credible. The following figures are made from the assessment roll of 1891, and include the exclusively agricultural land lying below an elevation of 1,500 feet, being all of the county west of a line drawn north and south two miles east of Auburn. Mining claims and towns are not included. The landholdings for more effective comparison are segregated into valley or plain lands, part of the Sacramento Valley; unirrigated foothill farms and irrigated foothill farms.

VALLEY LANDS.

Number of farms assessed	225
Total acreage	143,386
Average acreage per farm	637
Total assessed valuation of land	\$1,544,703
Average assessment of land per acre	10.77
Total assessed valuation of improvements	153,179
Average per acre	1.06
Total land and improvements	1,697,882
Average per acre	11.83

UNIRRIGATED FOOTHILL FARMS.

Number of farms assessed	599
Total acreage	85,313
Average acreage	142
Total assessed valuation of land	\$1,075,956
Average valuation per acre	12.61
Total assessments of improvements	161,684
Average per acre	1.90
Total land and improvements	1,237,940
Average per acre	14.51

IRRIGATED FOOTHILL FARMS.

Number of farms assessed	328
Total acreage	30,272
Average per farm (acres)	92
Average per farm irrigated (acres)	18.4
Total assessed valuation of land	\$715,501
Average per acre	23.63
Total assessed valuation of improvements	334,953
Average per acre	11.06
Total land and improvements	1,050,454
Average per acre	34.69

From these figures, and those of actual sales, the value of the unearned increment of the actually irrigated and bearing foothill lands is \$280 an acre, fourteen times the mean sale value of contiguous unwatered land in the foothills, and fifteen times the mean sale value of the valley wheat lands. The sale figures show \$100 an acre additional as the unearned increment of the bearing trees. The aggregate of these two for the 6,000 acres of irrigated land is \$3,800,000, all of which, and another undetermined amount in town real estate and improvements, is the earning power created by large net earnings from the sale of the small farm product, fruit. The actual amount of this unearned increment appearing on the assessment roll for the year 1891 was \$970,000. But the large net earnings of the land on which these values were based were not the net earnings of 1891, but of preceding years. In 1892 there was only a small profit margin, as closely as it can be estimated about 15 cents to the 25-pound box of peaches. In 1893 even that practically disappeared, and in this year of 1894 it has more than disappeared. Values remain, just as they do for the wheat lands, but, just as in the case of the wheat lands, they are only a survival, what was, not what is. They were wealth-producing, they are not now. The possessors cling to them only in the hope of realizing on them through a sale to some outsider who is not expert enough to comprehend the real condition.

The statistical figures already given, and some others here stated, furnish the basis for conclusions relevant to society as between conditions of large and small landholding, which are equally instructive with those presented in Mr. Mills' paper. The 6,000 acres of fruit farm lands in 1891 directly supported a population of not less than 1,500, and town population adjacent of 1,000, in addition contributing to the support of another distant population engaged in box- and paper-making. The 85,000 acres of unirrigated foothill farms did not maintain directly and indirectly more than 1,100 people. The 143,386 acres of plain farms furnished support for only 1,500 people. The density of the supported population is at the rate of 265 to the square mile for the small farm fruit area, and only seven to the square mile for the large farm areas. The latter has been for years decreasing in population, one town, Sheridan, has practically disappeared in the last ten years, and another, Roseville, is tending the same way.

On the small fruit farms are comfortable modern dwellings and conveniences, and the surroundings are made attractive, indicating leisure and the accumulation of wealth, or the anticipation of its accumulation. School-houses and churches are cheerful-looking buildings, and are well supported. The reverse of these facts is the rule of the other farms and their localities. While mortgages that cannot be accounted for, as the unpaid balance of purchase price of the land, expenditure for improve-

ments, or capital employed in other occupations, only amount to 12 per cent. of the assessed valuation of the improvements alone on the small fruit farms; on the valley farms these mortgages amount to the entire sum of assessment of improvements, and to 9 per cent. of the assessment of the land besides. The fruit growers are constant travelers by rail, the others are not. The 6,000 acres of fruit farms furnished, in 1891, 1,500 carloads of outgoing products, and 500 of incoming supplies, more than these figures rather than less. The 85,000 acres of other foothill farm, and the 143,386 acres of valley farm, during the same year, furnished in outgoing freight not over 500 carloads, and in incoming not over 150. The first pay high rates on long hauls, and the second pay for short hauls at low rates.

Placer County in itself shows the undesirable tendency toward the growth of large landholdings, and in itself as well as the desirable tendency toward the multiplication of small landholdings. The very closeness of contact of the two forces contrasts them the stronger. The causes that have been operating to make business failures of one class of agricultural industry, the causes that have operated to make business successes of another, are alike comprehensible and measurable. The relation of these two classes of causes to transportation is clearly defined. Nowhere is more clearly established the fact that the underlying value of a railroad is not in its track and rolling stock, but in its people and its country.

Now, if the wealth-developing power, which has made small landholdings desirable, can be maintained instead of disappearing, population will increase instead of decrease, the extension of large landholding will be checked, and ultimately turned the other way. On precisely even terms the small landholder will beat the large landholder in the economy of production, and will ultimately displace him. It is the certainty of the maintenance of the developed values, and the certainty of even terms between individuals, that is wanting. Neither exist. The decreased margin between the cost of production and the sale value of the small farm products has wiped out the possibility of profit, and with it the wealth development of the small landholdings. This is realized by the small landholders, and finds expression in efforts to reduce the cost of production along the line of least resistance. Labor has been reduced in remuneration till its compensation is so small that further yielding in that direction is impossible. The cost of packages has been pushed down to the unyielding point. No item of cost has not been too small not to have been magnified in relative importance and efforts made to reduce it. Taxation has been tinkered with, and precisely the wrong thing done. Irrigation water, which takes the least of the product and gives most in return, has been made the scapegoat for failure of profit.

These misdirected efforts to reduce the cost of production, misdirected because the aggregate of all of the possible gains is insignificant as compared with what is necessary, have created an uncertainty as to the future in the minds of those who should be best able to forecast it, that extends to all business enterprises that otherwise would be put in operation. Capital will not invest in colonization, irrigation or manufacturing in the face of this uncertainty. The element of security is wanting. It is the real reason why population and small landholdings are decreasing instead of increasing, for the small owner of wealth is just as anxious as the large owner to have security that he shall keep what he has gathered together.

The present industrial and trade condition in California is simply the logical resultant of the persistence for the last twenty-five years of the reckless business policy of its great distributive agency, the Southern Pacific Company. This policy had its inception at the close of the time and business methods when the production of California was wealth itself, gold dug out of the earth, not obtained as the difference of exchanges of consumable products. Taking all of this gold it could, it still left some to the producer, and the ultimate effect of its persistence was not foreshadowed. Persisting in its policy after the wealth-producing power of California became less in the gold taken direct from the earth, and more in the difference of exchanges of its sun and soil products, the amount taken has closer and closer approached the whole of this difference. The fruit production development, commencing ten years ago, was to the Southern Pacific Company like the old yield of the gold mines come back again. To the producers, the people, who brought that gold in from the inside, what the Southern Pacific took while waiting for their trees to bear was a part of their investment of capital, not a charge against their gross income, which would wipe out the possibility of their being any net income. The ultimate effect was not foreshadowed to these fresh producers, the old ones drained, remained silent, perhaps they, too, might find fresh producers. It has been the old fable of the goose which laid golden eggs over again, only California is a bigger goose than the one in the fable.

In this year of 1894 the logical resultant of the persistence of the reckless business policy of the Southern Pacific Company is an actuality, a fact. The earning power of some of the most sun-blest land on the earth has been pushed down below the profit point, and the land made undesirable, population has decreased, wealth has disappeared. That the business and industrial fabric stands at all is only because it is a habit, its real stability is that of a soapbubble, of wind.

In conclusion, if California is not to be a failure, action is an imperative necessity. Great as are her natural resources, the wealth they

have produced so far, and what is left of their wealth-creating power, has been made an appurtenance of the Southern Pacific Company. Not producing anything, merely distributive of the energy of producers, as its share for that distribution it is taking so much that there is nothing left for the producers. The remedy for this condition is obvious and simple. The Southern Pacific Company must take less of the production than it has been taking, not a little less, but a great deal less. It must take less, voluntarily if it will, if not it must take less by being made to. It is either that remedy, or else——

There is just one other stage of California landholding. Mr. Mills does not state it, but it is just the same inevitable under the persistence of existing conditions. The State will have just one land monopolist—the Southern Pacific Company.

DISCUSSION.

W. G. CURTIS (Member Tech. Sec.).—The particular points of the subject-matter covered by this discussion relate to the question as to whether or not California railway rates tend to promote land monopoly, and to the effect of the policy governing railway rates upon the growth of Placer County.

I am glad the Technical Society thinks it proper to admit subjects appertaining to the questions treated in Mr. Dunn's paper.* In its membership the Society embraces a wide range of industrial activity, and there is no good reason why we should not deliberate upon social questions, and concern ourselves somewhat with the problems of political economy, as well as with the physical sciences.

The principle of inertia, as affecting social progress, is akin to the operations of the law in physical nature. The industrial development of a country, once started in the wrong direction, can be turned therefrom only by the application of some force, which may, and in times of peace, is very likely to be a long time in producing visible results.

To begin with a little familiar history, the first reference to the region now covered by the State of California, found by historians, is in the old Spanish records of a report transmitted by Cortez to Emperor Charles V. of Spain, in the year 1524, wherein it is represented to be "an island rich in pearls and gold." The peninsula of California, now known as Lower California, was discovered by Fortuno Ximenes during his expedition in Cortez's ship, "La Concepcion," in 1534. The name "California" seems to have been first applied by Cortez, who found it in one of the romances of chivalry written about the year 1500, wherein it

* On same subject read before the Society, September 7, 1894.

was used as the designation of an island "on the right hand of the Indies, very near the terrestrial paradise."

The Spanish voyagers, Cabrillo and Ferrelo, sailed along the entire Coast of California in the years 1542-43. Sir Francis Drake, coasting the eastern shore of the Pacific searching for the much desired northern passage, supposed to connect the two great oceans, landed at Drake's Bay in 1579. The country was then inhabited by a small number of Indians, probably not exceeding 10,000, living in the hunting and fishing stage of economic development.

Early in the eighteenth century there is supposed to have been some expedition to the southern part of California by the Jesuits, but no systematic settlement of the country was accomplished until the year 1769, when the Mission of San Diego, in the southwestern corner of the State, was founded by the Franciscan Monks. The Mission of Monterey was established a year later, and about a year after this the Mission Dolores was founded in this city.

In 1805 the population of California, as registered at nineteen missions and some half dozen villages, was stated to be 22,800, of which 20,600 were native Indians. In 1826 the total population was stated in the old church records as 24,614.

While the old fathers, almost simultaneously with the founding of the mission churches, began on a small scale the practice of irrigation, at once planted many of the present characteristic fruits of the State, and otherwise demonstrated the fertile qualities of the land, the country was regarded by the Mexicans and Spanish settlers as suited chiefly for cattle-raising, and when, in 1848, by the treaty of Guadalupe Hidalgo, California was ceded to the United States, the latter took the country pretty much at the Mexican estimate, as suited only for pastoral pursuits.

Almost simultaneously with this cession of California to the United States, gold was discovered, and a year later thousands of gold-seekers were prospecting along the ravines and hillsides, eager in their search for gold, but with no thought of any other productive capability of the State than cattle and precious metals. Consequent upon this view, which prevailed for many years after the advent of the gold-seekers (and the writer well remembers in Mr. Dunn's part of the country, as late as 1864, the prevailing sentiment among the people was that sooner or later the mines would be exhausted and the miners would return to their Eastern homes, leaving the country once more in the possession of the Mexicans and Indians), our Government agreed to sustain the titles to Spanish grants, some 350 in number, covering an aggregate area of over 8,700,000 acres, or from 25 per cent. to 30 per cent. of what the best authorities set down as the total arable area of the State. These 8,700,000 acres cover the best valley lands of California.

A few far-sighted Americans, deserting the ranks of the miners and affiliating with the Spanish grant owners, found many ways of extending their landed possessions over Government land and railroad grants, and thus keeping up the holding of land in great tracks. The salient facts in this connection are well set forth in the paper referred to by Mr. Dunn. As a result of this, when it became apparent, even to the dullest mind, that California was not only a pastoral country, not only a mining country, but a region of almost unbounded possibilities for the production of all the fruits grown in the temperate and semi-tropic regions of the world; when it was realized that the occasional peach-tree, apple-tree and grape vine, successfully planted here and there in front of the miners' cabins in the foothills, as well as the fig, the orange, the olive, and other semi-tropic trees, thriftily growing around the old mission churches, all proclaimed the capability of the surrounding country to abundantly produce these and similar fruits; and when it was demonstrated that nearly everywhere in the State farms of from 10 to 160 acres could be profitably cultivated for fruit raising, the greatest obstacle standing in the way was the large landholder, wedded to the idea that farming operations in this State are feasible only on a great scale; the cattle-raiser having his broad Spanish grants for pasturage and the grain farmer measuring his fields by the thousands of acres.

Fortunately for Placer County and many other localities in the State, the seeker after large landholdings did not much value the foothills, so when the time came for beating the spear of the miner into the pruning-hook of the farmer, lands lying along the lower mountain slopes could still be acquired, in small tracks, from the Government and other sources, for horticultural operations. According to "Resources of California," published last year under approval of the Governor, the shipments of fruit for 1892 from Placer County aggregated 1,125 carloads. The same publication contains the statement: "One-fifth of the deciduous fresh fruit shipments from California to the East in 1892 was made from Placer County—mainly from a section 12 miles long and 5 miles wide." The great capabilities of the foothill regions of California are apparent when we reflect that along the westerly flank of the Sierras, under 4,000 feet altitude, between Redding on the north and Bakersfield on the south, there is a belt of arable foothills, over 400 miles long, all in greater or less degree similarly capable of producing fruit.

While the population in some of the agricultural counties, where large landholdings prevail, has diminished, it is also the case with several of the mining counties, which are situated at such a distance from railway transportation that they have not developed their agricultural resources. Placer County, however, stands in the front rank of the old

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mining counties which have steadily advanced, the population and assessed valuation of real and personal property from 1870 to 1890 being as follows :

Year.	Population.	Assessed value real and personal property.
1870	11,357	\$4,063,639 00
1880	14,232	5,774,860 00
1890	15,101	10,118,060 00

The Hon. Jeremiah Rusk, Secretary of Agriculture, doubtless having just such localities as Placer County in mind, said, after his return East from a visit to this Coast :

"The enormous yield of the vineyards and orchards are facts which are but little known to the majority of the people, and but few even of those who know them realize the full meaning. To the Eastern man who has tilled the farms of twenty and forty acres that his father tilled before him, the farms of this great State (California) are as legends of fairyland, and when told that, with the same energy he expends on his forty acres, he can farm in California four times forty acres, he becomes incredulous—he cannot imagine such farms as I have seen in that State."

Mr. Dunn puts the query: "Are decreasing population and increasing land monopoly the cause of the condition of fares and freights, or is it not the fact that the condition of fares and freights is the cause of decreasing population and increasing land monopoly?" When contrasted with the Mississippi Valley States, where, at the commencement of the development of agricultural resources, land was owned by the Government, and could be obtained at the minimum price, it is seen from the foregoing, that when the agricultural and horticultural possibilities of California were perceived the land was already monopolized. I am unable to see where anything connected with, or dependent upon, railroad transportation runs in the direction of favoring the aggregation of land into large holdings. Before the railroad was constructed, and the cultivation of fruit in California for sale beyond its borders was made possible by affording the means to reach the market, in competition with local grown similar productions 2,500 to 3,000 miles away, practically the only industries connected with the use of the soil were cattle-raising and grain-growing. As to the transportation of grain, which in general reaches the ultimate market by ocean carriers, the railroads of California can have but little to do beyond moving it from the fields to tidewater. Sacramento Valley, the principal section of the country treated of in Mr. W. H. Mills' paper of two years ago, referred to by Mr. Dunn, has a navigable river running throughout the Valley, open at all seasons of the year. This is one of the greatest grain-producing sections of the State. It is not possible that the railroad rates for transportation of grain to tidewater from this region have

been excessive, otherwise the shipments would have been made upon the navigable river; the railroad, if unreasonable, would have got nothing to haul. The fact that it has obtained its full share of this traffic is well known, and must be taken as *prima facie* evidence of the reasonableness of its rates.

Mr. Dunn says the income he figures on ten acres may be "an inducement for labor, but it is absolutely none for the investment of capital in ten-acre landholdings." I apprehend that California's need is not so much to attract the capitalist into fruit-growing as to develop it for the small farm-holders who reside with their families on the land. Mr. Dunn has selected ten acres as his typical small fruit landholding. Possibly such a farm is too small to be reasonably profitable; then why not try twenty acres? Mr. Mills and his friends do not insist that ten acres shall be the limit; their contention is, rather, that the holding of lands, as, for example, in one hundred 16,000-acre farms in the Sacramento Valley is not as good for the State of California as if the same land was divided up into small holdings. Mr. Mills, as I remember, comments on the possibilities of fifty-acre farms, but in stating his conclusions takes 100 acres and computes that 100 landholders whose holdings embrace 1,654,000 acres of land displace 16,540 families, each having 100 acres of land. If these 16,000 families should occupy the land now held by the 100 men, and turn their industries toward the production of grain, they would control the railroad rates, if necessary, by shipping their products out by river. Should they raise fruit and seek a market over in the Eastern States, the railroad companies could be depended upon, if necessary to profitably market the product, to continue as they are now doing and move it to market at the cost of carrying. More than this the railroads cannot do, and under such conditions they cannot be justly charged with retarding the development of the country. With land monopoly established, the lowering of railroad rates (in the Sacramento Valley for example) would only tend to perpetuate such monopoly, because transportation could be had by these large landholders free for the asking, their large-scale operations would be still more profitable, and they would be more disinclined to cut up their land and offer it for sale in small parcels.

The tone of Mr. Dunn's letter is in line with the popular fallacy that somehow, by some means, the Southern Pacific Company has managed to hold up its rates and its earnings, while the producers whom it serves are becoming slowly impoverished. As an indication of the facts, let us look at the course of the Southern Pacific System's average rates on commercial freight from 1872 up to the present time:

Year.	Av. rate per ton per mile (cents).	Av. rate passenger per mile (cents).
1872	3.66	3.83
1880	2.68	3.16
1888	1.93	2.21
1893	1.57	2.11
1894 (first seven months)	1.32	1.80

These little figures, indicating that the current passenger and freight rates are both less than half the rates in 1872, when times were certainly good in California, are not very impressive, but if we apply the rates of 1872 to the commercial freight and passenger traffic of the Southern Pacific Company's Pacific Coast lines in 1893, we find that, at the 1872 rates, the earnings for 1893 would have been over \$35,000,000 greater than they actually were, and had even the rates for 1880 been earned on the traffic movement of 1893, the earnings would have been nearly \$19,500,000 more than actually taken in by the Company. So far, then, from fixing its rates and standing to them, regardless of the necessities of its patrons, the Southern Pacific Company has, by the adjustment of its operations to the commercial conditions and necessities of the Pacific Coast, lowered its rates until it has, of its earning power, given up to its patrons, even as compared with 1880, a period when the fruit industry was just beginning to become a factor in transportation, nearly \$20,000,000 per year.

The fruit from Placer County starts East over the Central Pacific line and is delivered to connecting lines at Ogden. The division of the through rates to Eastern markets being made between all of the lines on a mileage basis, the Central Pacific conceding a division on this basis in order to bring the Eastern connecting lines to an agreement on the through rates demanded by the fruit shippers, though, by reason of the greater physical obstacles to be overcome and its other operating disadvantages, the Central line is entitled to a larger proportion of the rate. It concedes to its Eastern connections the division of the through rates to Eastern points on about an even mileage basis, but before starting on its Eastern journeys the freight is lifted on the Central line 7,000 feet above the sea, the expenditure of power requisite to move a ton of weight to the summit of the Sierras being equivalent to the power necessary to move the same ton 450 miles on a level grade. The cost of fuel on the Central Pacific line in California, delivered on tenders, averages \$4.80 per ton, as against \$1.57 per ton on the Union Pacific, and from \$1.36 to \$1.82 per ton on the various lines from Council Bluffs to Chicago.

The Interstate Commerce Commission, under the rule established by them, and which unquestionably produces results as near the truth as possible, find and report the cost, for operating expenses only, of

moving one ton of freight one mile on the Pacific System lines of the Southern Pacific Company (averaging the valley levels with the steep mountain gradients) to be from $\frac{9}{100}$ of a cent to 1.02 cents per ton per mile.

The average rate per ton per mile for transportation of California orchard and vineyard products to market in the Eastern States does not now exceed $\frac{9}{10}$ of a cent per ton per mile, a sum merely equal to the average cost of operation for maintenance of way and structures, conducting transportation, etc., contributing nothing, however, available for the payment of taxes, interest upon the bonded debt, and other necessary and legitimate fixed charges.

While we are accustomed to hear the railroads denounced for not paying their taxes, I find it to be a fact that the Southern Pacific lines have paid into the State and County treasuries of California a little over \$8,000,000 in payment of their taxes for the past fourteen years. In the same fourteen years the sum total received by the Southern Pacific Company for hauling (not only through California, but also through Nevada and Utah, and through Arizona and New Mexico) fruit shipped from California to the Eastern market has been for

Green deciduous fruits	\$3,710,221 00
Dried fruits	1,704,593 00
Canned fruits	1,982,273 00
Or a total for all deciduous fruits of	<u>\$7,397,087 00</u>

say in round numbers \$7,500,000, or a half million dollars less than the amount of California taxes paid in the same period.

Another fact of interest to Californians is this: An investigation made about three years ago by one of the officers of the Southern Pacific Company developed a condition which doubtless remains true up to the present time, namely, that by reason of the fact that there is no lumber or other materials needed for current repairs of the railroads in Arizona, New Mexico, Nevada and Utah, large quantities of supplies required for the maintenance and operation of the Southern Pacific roads in these States and Territories are purchased from California producers, dealers and traders, the total amount of such purchases exceeding the Southern Pacific earnings from the strictly local movement of freight and passengers within the State of California.

The Central and Southern Pacific lines have pioneered in the building of railroads in advance of industrial development, and must be content to await results, which are sure to follow, bringing the full measure of prosperity to all interests. In the meantime, they must earn for the capital invested fair rates of interest, must pay for the materials and supplies necessary for the maintenance of their property, and

must pay the men whose services are necessary for its operation. The railroads are carrying at bedrock rates, and if it is true that the fruit-growers are also in distress, it is time to look in some other direction than a further lowering of transportation charges for a means of restoring living prices to both the producers and railroad companies. The middlemen are useful, but it is well to inquire whether they are not making too much profit when we find, as was recently ascertained to be the fact, that dried fruit sold by the California producer at six cents a pound, hauled over by the Southern Pacific and its connecting lines to Minneapolis, for a trifle over a cent a pound, is sold to consumers at the latter place for fifteen cents per pound. In such cases it does not appear that either the producers or the railroad companies are getting what is fairly their due. It is not likely that the middlemen and dealers in general are dividing up profits at this rate, but if it is true that, as a rule, they are taking more than their share, the obvious remedy is the adoption of some means for bringing the producer and consumer closer together. Fruit exchanges, such as appear to be in successful operation in Fresno, Santa Clara and Riverside Counties, indicate a step forward in the right direction.

The existing method of preserving the fruit against decay, in transit, are expensive, not only to the shippers, but to the railroad companies obliged to use up their power in hauling the great dead, or non-paying, weight of refrigerator cars; but there are hopeful possibilities of a reduction in this expense. Experiments have recently been made for producing the refrigeration for the preservation of fruit in cars by the expansion of compressed air, or by supplying into the cars air which has been sterilized by an admixture of antiseptic gases. The success of these experiments would effect a great reduction in the cost of preserving fruit *en route* to the East.

The California small farm owners are not quite living up to their opportunities for supplying our local markets. That there is room for a profitable development in this direction is evidenced by the fact that last year there was brought, by rail lines, from the East into the Pacific Coast States, practically all of it coming into California, 39,945,000 pounds, or about 2,000 ten-ton carloads, of stock-farm and poultry-yard products, in their natural state or manufactured into staple commodities; over 36,000,000 pounds of this tonnage was composed of articles of food, such as butter, cheese, poultry, meats in bulk, lard, eggs, condensed milk, etc.; the shipment of eggs alone amounting to 5,500,000 pounds. In addition to this, in 1893, there was shipped from the Eastern States and foreign countries into California, by rail over 13,000,000 pounds, and by sea about 70,000 packages of canned goods, including fish, oysters, canned meats, canned corn, and other vegetables. Undoubtedly articles

corresponding at least to one-half these goods are now, or could be, produced in California.

Of other articles annually shipped to the Pacific Coast from Eastern States, or imported from foreign countries, which might be supplied by California farmers, may be noted over 9,000,000 pounds, shipped by rail, and about 900 packages, by sea, of alcohol and spirits; over 1,250,000 pounds by rail, and about 1,500 packages by sea, of dried fruit and dried currants; nearly 1,250,000 pounds of oats; over 1,000,000 pounds of pickles, preserves and jellies; over 3,700,000 pounds of cornmeal and oatmeal; nearly 1,250,000 pounds of farm and garden seeds; nearly 2,000,000 pounds by rail, and over 11,000 packages by sea, of wines; nearly 1,500,000 pounds of broom corn and brooms; over 60,000 pounds, by rail, and about 14,000 packages, by sea, of olive and salad oil, not to mention "coals to Newcastle" in the shape of over 9,000,000 pounds, by rail, and 1,000 packages by sea, of flour.

In the way of other things that California can likely produce for the supply of local wants and the general markets of the world, are textile grasses, flax, hemp, jute, and fibrous vegetable substances other than cotton. The value of these raw materials and articles manufactured therefrom, imported into the United States for the year ending June 30, 1893, was, in round numbers, \$49,500,000.

California is still in the experimental stages of its development, and when the supply of any one of its peculiar productions approaches the demand of existing markets, the profits of the industry, pending the building up of new markets, are likely to be uncertain. The railroad companies cannot always stand in the breach between the producer and the consumer in such a way as to always insure profits to the former. When they sacrifice their profits to the necessities of their patrons, get down with them to a cost basis and move any commodity for the mere cost of carrying, they cannot be justly asked to go further. Notwithstanding all that has been said to the contrary, the fact remains that the railroad companies of this State have consistently shown by their acts that they are working in full sympathy with the industrial interests of the communities they serve.

Knowing their integrity of purpose in this direction, the managing officers of the Southern Pacific Company are well pleased to accept every challenge to fair discussion of their business relations to other people, realizing that the facts, fairly stated, lead to no other conclusions than that their business methods are just and reasonable.

NOTES ON THE CONSTRUCTION OF THE EAST RIVER GAS TUNNEL.

BY WALTON I. AIMS, C.E.

[Read before the Boston Society of Civil Engineers, April 17, 1895.]

DURING 1891 and 1892 the East River Gas Co., of Long Island City, a corporation with works situated on the Long Island shore of the East River, obtained from the New York State Legislature a new charter, and such necessary legislation as to permit the extension of their mains across the East River into the city of New York. This project had many important features to recommend it. New York, with an average of 45,000 inhabitants to the square mile, presents, to a gas enterprise, the favorable conditions of a much concentrated population. The citizens have long been strenuous in their efforts to abate all nuisances surrounding their dwellings, and they are quick to appreciate improvements in that direction. As the manufacture of gas in the heart of the city has been found very objectionable, the location of such works outside of the city is an important consideration. For another reason, the location of the works of the East River Gas Co. was most happy; for while so situated as to derive the benefits of the enormous difference in value between city and suburban real estate, yet these works are directly opposite the heart of the residential district of New York and but half a mile distant from the city. Here twelve acres of land had been secured for plant purposes, with a river frontage of over 800 feet, on which there is sufficient room for the erection of a plant of 50,000,000 feet daily capacity.

The most important point in this whole enterprise was how to bring the gas across the East River. The feasibility of constructing a tunnel under the river through which the gas mains might be laid was discussed, and after some preliminary surveys and examinations a route was decided upon from the works of the company at Ravenswood, Long Island City, to between 70th and 71st Streets, New York, passing under Blackwell's Island and the east and west channels of the East River. On about this line of location some eight or ten pipe soundings were made in the two river channels, all of which indicated a rock bottom; and the results of these, together with surface indications, where at both the Long Island and New York shores, as well as on Blackwell's Island, bed-rock lay exposed, led all to conclude that nothing but rock was to be encountered. On these investigations a contract was entered

into on June 25, 1892, for the construction of a supposedly rock tunnel, which the contractor guaranteed to complete by April, 1893.

Work was begun at the Ravenswood or Long Island side on June 28th by sinking a shaft about 200 feet back from the river 9 feet square, to a depth of about 148 feet below the surface; while at New York, on July 7th, a shaft of the same dimensions was started on private property fronting on 71st Street and East River, and sunk to a depth from the surface of 139 feet. In both these shafts rock was entered after about 8 feet of soil; but while the rock at New York was quite dry, at Ravenswood it proved seamy and very wet.

The tunnel-roof grade had been established at 109 feet below mean high water at the New York shaft, with a grade for drainage of one-half of one per cent. towards Ravenswood. This gave a minimum cover of 41 feet at the deepest point in the west or New York channel of the East River, where there is 70 feet of water at mean high tide. The east, or Long Island channel, is comparatively shallow, the deepest point being only 35 feet below mean high water level. The one thing feared was that fissures yielding large volumes of water might extend to the tunnel roof and largely augment the cost of pumping. The size of the tunnel section was to be 8 feet 6 inches in height by 10 feet 6 inches in width, this giving sufficient room for the laying of two 3-foot gas mains and one 4-foot main.

In the shafts, on both sides of the river, the headings were now turned. At Ravenswood the work was delayed by meeting considerable quantities of salty water, but at New York the tunnel was practically dry until towards the end of December, 1892, when, at a distance of 338 feet from the shaft, a fissure was struck yielding about a three-inch stream of salt water. The rock to within 20 feet of this point had been the regular hard New York gneiss, with a dip towards Long Island of 10° from the vertical, and a strike north and south at right angles to the direction of the tunnel. Here it gradually began to soften, becoming more and more micaceous until when about 20 feet beyond the water-bearing fissure the rock suddenly terminated, running into a vein of soft material with the same dip and strike as that of the rock.

This new material proved to be a vein, principally of decomposed feldspar, gray in color, crumbling easily, and with no perceptible grit. It still preserved a rock structure, and was perfectly dry when undisturbed. But its exposed surfaces were quickly acted upon by water which it would absorb and then wash away quite rapidly. The water-bearing fissure and this soft vein were connected; more water was also met at the junction of the rock and the soft material, and later experience proved that in passing through these soft veins water was always to be found next to the rock—a sort of water-course on both sides of the soft vein.

Had it not been for encountering this water, the tunnel might have been carried through the soft material without employing compressed air, though the prudence of attempting this might be questioned, for nothing more insures the safety of both the men and the work than compressed air in sub-aqueous tunneling.

The finding of this soft material, so unexpected, was quite a set-back to all concerned. However, it was decided to drive a small timbered drift about 4 feet wide by 6 feet high to investigate the ground ahead and find how much of this material was to be penetrated before solid rock was again met. This drift was started and driven in for about 6 feet. Meanwhile a most destructive action was going on between the water and the soft material. The water running along the face of the rock had washed out a cavity overhead in the soft ground. The walls of this cavity were gradually breaking away, and the clay-like substance falling down would close the outlet of the water into the tunnel. The water would then accumulate in this pocket, softening up fresh material on the sides until it had gained a sufficient head to burst through the dam which confined it, when it would come rushing into the tunnel, carrying with it large quantities of the softened material. These rushes were accompanied by a loud bubbling sound that quite mystified the men, which was, of course, the sound of the air displacing the water in the cavity. As soon as the pocket had emptied itself, for a time the trouble was over until with the falling of more material the outlet was again closed and the operation was repeated.

These rushes of water, with the accompanying sound of the bubbling air, soon became more and more alarming to the men. The cavity was constantly increasing in size, and extending up toward the river bed. Each recurrence would now send the men running for the shaft, by no means certain that the river had not at last made a connection with the tunnel.

All work in the small drift was abandoned, and on December 31st a bulkhead was hurriedly constructed, at the face, to prevent the threatened flooding of the shaft. Up to this time over 25 yards of material had been washed into the tunnel, all of which had come from along the rock face. With the river bed only 45 feet above the tunnel roof, there is every reason to believe that this bulkhead was put in none too soon, and a connection with the river narrowly averted. The bulkhead was well packed with hay to prevent, as much as possible, further washing of the material, and a discussion was now entered into as to the method of future procedure. The contractors were in favor of abandoning the heading and returning to the shaft, to sink to a lower level and start anew in hopes of meeting more favorable conditions at a greater depth.

There had been a somewhat similar experience on the Croton Aqueduct, where that tunnel passes under the Harlem River. Soft material had been encountered on the first established level, which proved so troublesome that after two or three unsuccessful attempts had been made to pass through it, it was finally decided to abandon the heading and return to the shaft, sinking some 150 feet deeper. On this new level nothing but rock was encountered. In the East River tunnel, however, the soft material was clearly a decomposed vein, and to what depth this decomposition might extend was unknown; so that as there were no well founded reasons, in this case, for expecting any better conditions at a lower level, it was decided to first attempt to drive the present heading, in compressed air, leaving the sinking as a later expedient should the proposed means fail.

An arrangement was made with the contractors by which the company was to share the expense of the work in soft ground. It was at this time that the writer became connected with the work, having charge of installing and conducting the compressed air operations for the Company.

To form the compressed air-working chamber, a solid brick wall or bulkhead 8 feet thick was built across the tunnel into gains in the rock about 40 feet back from the heading, and containing a cylindrical steel air-lock 6 feet in diameter and 10 feet long.

In the engine room, the 18" x 24" Ingersoll piston-inlet compressor, used heretofore for running the rock drills, was supplemented by a small Rand compressor, and both arranged to supply, independently, compressed air to the working chamber below. Incandescent electric lighting was introduced into the tunnel, which is almost a necessity in compressed air operations, as common illuminants produce an enormous quantity of smoke, when burning in compressed air. A telephone was also taken into the working chamber, by which instant communication could be had with the engine room in case any sudden increase of air pressure should be desired.

On February 25, 1893, operations were commenced, in the heading, under 35 pounds of air pressure. The previous work here had greatly increased the difficulties, and it was not long before the air pressure had to be raised to 42 pounds to control the water.

The excavation was advanced under a cylindrical steel roof, built up of plates 3 feet long and 1 foot wide, of $\frac{3}{8}$ " sheet steel, to the four sides of which were riveted angle bars $2\frac{1}{2}$ " x $2\frac{1}{2}$ " x $\frac{1}{4}$ ". These plates were bolted together in a heading about 6 feet high. In the erection of this roof, poling boards were used for each plate, and a bulkhead carried down with each ring as erected. When the heading had been advanced about 20 feet from the rock, a 12" x 12" yellow pine mudsill

was introduced along the bottom of the heading, and on this the roof was carried by means of radial timber bracing. The excavation was now carried down on both sides of this mudsill, to a distance of about 10 feet from the rock, the steel roof being extended well down on the sides. A circular section was thus excavated, in which brickwork was laid, four courses thick, and with an internal diameter of 10 feet. Between March 4th and 16th a great deal of trouble was experienced. Air pressure was several times to 48 pounds, and the work progressed very slowly on account of the many inrushes of water, and softened material. It was not until the 8th of April that the last section of brickwork in the soft material was completed, and rock again entered, after passing through 29 feet of this decomposed material. Of the material met in driving through this vein, at first 9 feet of the gray decomposed feldspar was penetrated, a vein of 4 inches of hard quartz was then met, and this was followed by 6 feet of pure white decomposed feldspar, smooth and soft as plaster. The remaining 14 feet was made up of layers of feldspar and chlorite. This chlorite, deep green in color, flaky, and grease-like to the touch when wet, proved to be very troublesome material, as it was easily converted into a fluid state by the water, which was again encountered next to the rock.

At the Long Island shaft, the work up to this time had progressed to about 250 feet from the shaft. The material so far encountered on this side was a hard, seamy gneiss, bearing considerable quantities of salty water, containing iron, lime and magnesia. Soft ground was now met at this end, in a seam about 4 feet wide, of chlorite.

As this material was perfectly dry and not thoroughly disintegrated, the tunnel was timbered through this seam without difficulty. Several similar veins were thus met and passed through, until at a point 285 feet from the shaft, where after drilling for about two feet through rock, a soft green, almost liquid chlorite vein was struck, which began flowing in through the drill holes with great force.

These holes were plugged, but as it was necessary to know what was ahead, and as with 100 feet of cover between the tunnel roof and the river bottom it was thought that the condition of affairs could not be very serious, it was decided to continue driving ahead without air-pressure, and with a timbered heading. To see what the material would do, several hand-holes were put into the rock-face with the object of blasting out a hole about 2 feet square through the remaining 2 feet of rock, to the chlorite. Before blasting, however, the precaution was taken to build a bulkhead, some 40 feet back from the face. On firing the holes, an inrush of many yards of material took place, which was finally checked by some rock fragments closing the opening through the rock.

After several desperate attempts on the part of the contractors to control this material and make progress, the work was finally abandoned in the latter part of March, and as a 4-inch stream of water was now flowing from the heading, pumping was discontinued, and the shaft and tunnel allowed to flood.

At the New York end, work was still being carried on, in compressed air. The rock encountered at the other side of the soft seam closely resembled the decomposed material which had been penetrated before, and consisted of alternate layers of feldspar and chlorite with an occasional vein of quartz. It was quite soft, though requiring drilling and blasting, and eventually it had to be lined. After the heading had been driven about 69 feet into this rock the company decided, in spite of the uncertainty as to the material ahead, to remove the air pressure, and to call upon the contractors to resume their contract. Upon removing the air-pressure, however, the brickwork through the soft seam proved so unsatisfactory in excluding the water, that air-pressure was again put on, and it was decided to line the brickwork with a circular cast-iron lining. Although this brickwork was only 10 feet in inside diameter, a lining was designed 10 feet 2 inches in the clear, as it was now desired to make the tunnel bore as large as possible. To put in this lining, some of the brickwork had to be cut out, which was then removed in sections, enough for one ring of plates at a time. The lining consisted of rings of plates or segments, each segment being about 3 feet long and 1 foot 4 inches wide, with internal flanges 4 inches deep, from the back of the plate. The metal in both the back of the plate and the flanges was $1\frac{1}{2}$ inches thick. All the joint-faces of the segments were planed and 1-inch bolts used for fastening them together. A complete tunnel ring was composed of nine segments and a small inverted key, about 8 inches wide. Difficulties between the company and the contractors, which had been brewing for some time, now culminated and the courts were appealed to to settle their differences. This caused a cessation of work for a short time until the company were empowered to take possession and resume the work of construction for themselves. The work of putting the cast-iron lining into the brickwork was necessarily a very slow operation. The lining was extended well into the rock on both sides of the soft vein, and a wall built at both ends between the rock and the iron lining, to confine the Portland cement grout which was now introduced back of the plates. To effect this grouting $1\frac{1}{2}$ -inch holes had been drilled and tapped through the back of several plates in each ring. Through these holes the grout was pumped by means of a Cameron pump, and after the space between the brickwork and the lining had been thoroughly grouted, the work was found, on taking off the air pressure from the heading, to be perfectly water-tight. It was

not until toward the end of July that the work of lining the brickwork was completed and driving ahead in the rock was resumed. Then, when an advance of only 10 feet had been made, a second soft seam was encountered about 80 feet beyond the first one, and a test pipe was driven to a horizontal depth of 70 feet without encountering anything solid. To avoid further delay the driving of the test pipe was discontinued at this depth and preparations made for advancing the heading. For this test pipe 1½-inch common wrought-iron pipe was used, which was driven in by a small machine-drill and washed out at each lengthening of the pipe with a ¾-inch wash pipe. From these washings the different materials penetrated were sampled, with the following tabulated results:

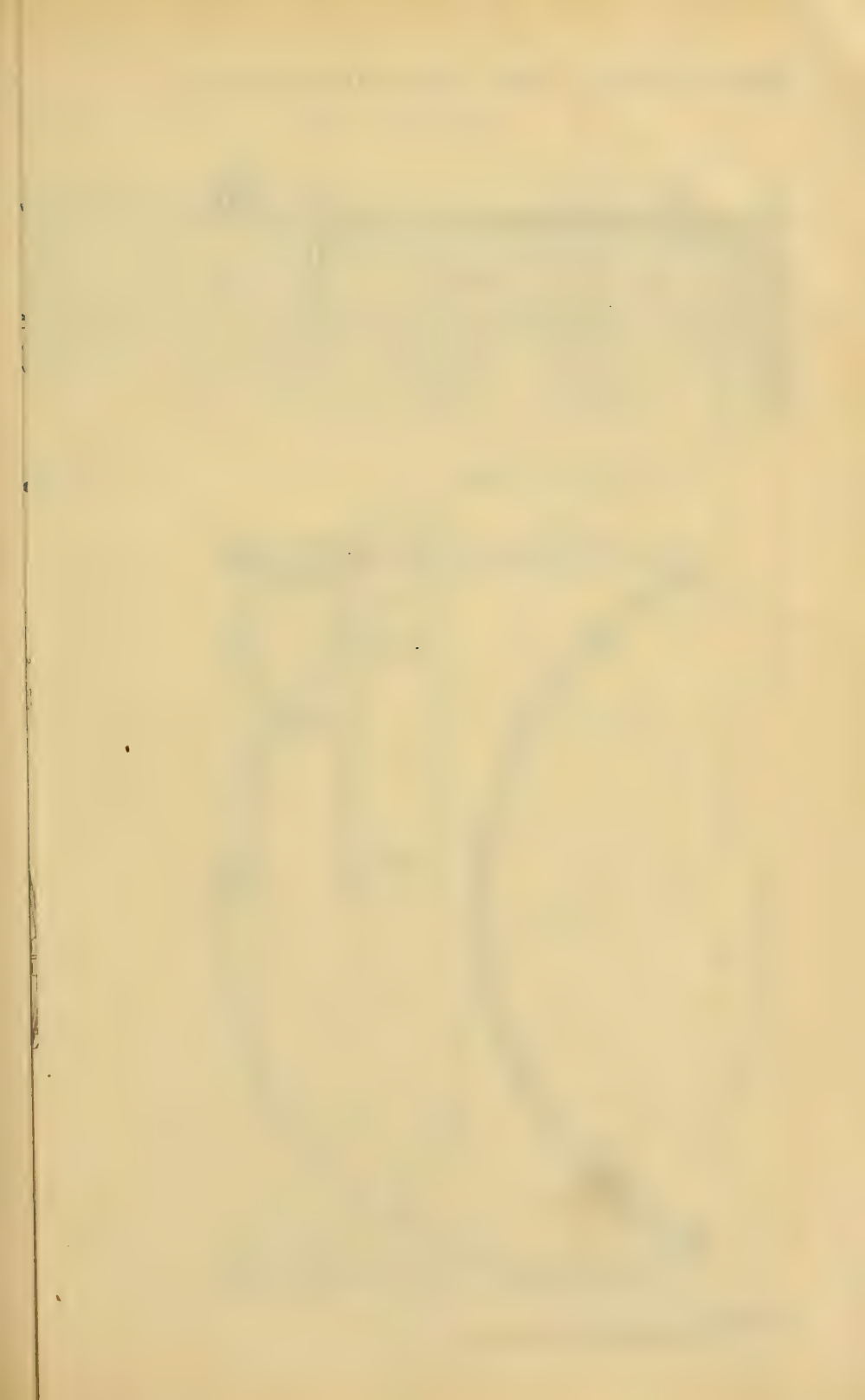
- 3 feet gray decomposed feldspar and chlorite.
- 11 feet soft black mud, containing lumps of carbonized wood like charcoal.
- 19 feet hard black mud and sand, with nodules of pyrites.
- 22 feet gray decomposed feldspar.
- 4 feet decomposed feldspar and chlorite.
- 11 feet gray decomposed feldspar.

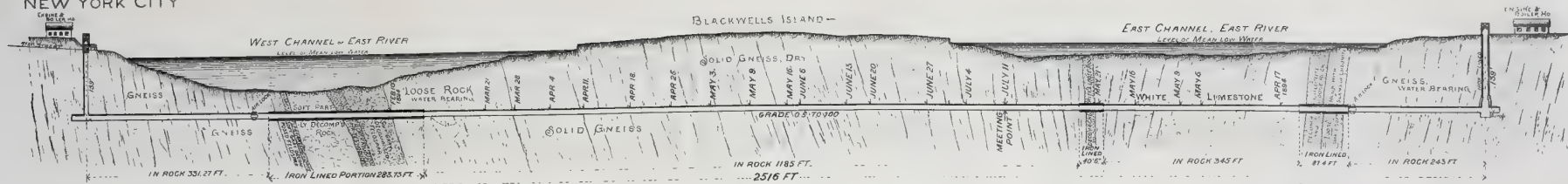
Water was again found next to the rock, but was considerably held in check by the compressed air. As from the results of the test pipe there were no special difficulties to apprehend from the indicated material, it was decided to drive ahead, under the open heading method, as this involved no delays in waiting for special machinery. The light steel cylindrical roof was again used in advancing the excavation, but for the permanent lining the cast-iron rings were to be introduced instead of brickwork, as heretofore. A start was made on the 7th of August to drive the heading into the soft material, but two days later, after the work had been advanced six feet into the soft vein, orders were received to suspend all work on account of the great financial depression of the time. This was unfortunate, and could it have been anticipated a few days the heading into the soft material would have been left unopened. As it was now, from being first disturbed and then abandoned, the water was allowed to soften up the black mud in the heading, and, in spite of the bulkhead, a considerable quantity of the material was washed into the tunnel. This stay of proceedings was utilized by making horizontal test boring in the heading on the Long Island side. At this shaft, no work had been done since the departure of the contractors beyond the building of a brick bulkhead and air-lock in the tunnel. Compressed air had then been put on, which considerably reduced the amount of water flowing into the tunnel from the heading. The action of the compressed air had been somewhat peculiar, for notwithstanding the great depth of the tunnel below the river bed, at 10 pounds pressure the air began to

escape through the heading, and with a pressure of 35 pounds per square inch small bubbles of escaping air could be seen rising to the surface for over 300 feet, up and down the river. This seemed to indicate that the ground above the tunnel had been honey-combed up to the river bottom by the previous washing-in of such quantities of the soft green chlorite. As it was known that there were detached lumps of rock in this soft vein, 2-inch heavy pipe was used for the test boring, with drive-well couplings, and a circular, hollow steel bit for the cutting end. This pipe was driven in the same way as the one on the New York side, and after passing through chlorite and various kinds of soft rock fragments, solid rock was again met at 32 feet. Into this rock a hole was drilled to a depth of 54 feet, using a small bit on the end of a 1-inch pipe and drilling through the test-pipe. The rock beyond the soft seam was a soft white limestone.

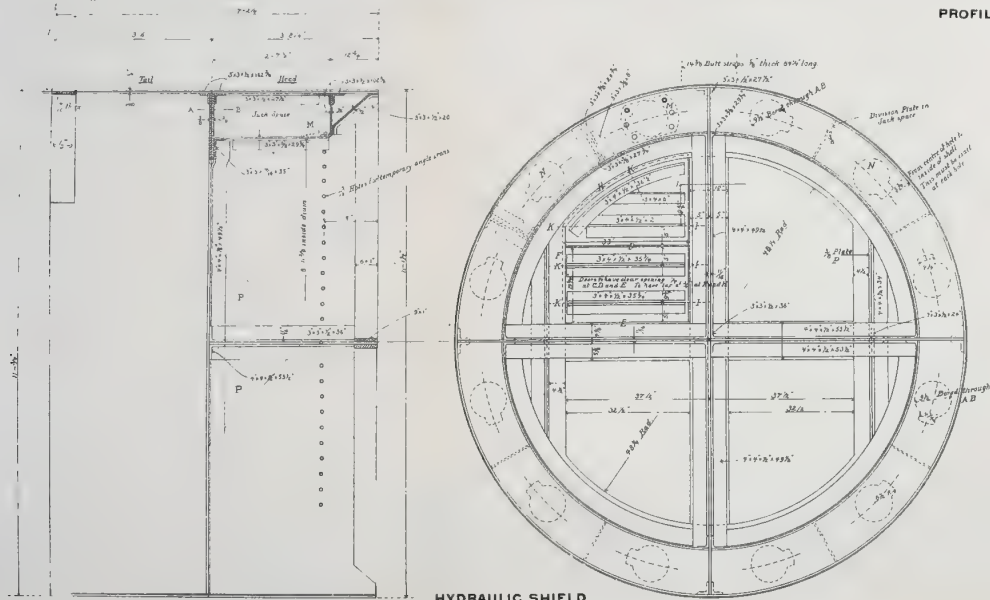
With the prospect of resuming work the question now arose as to the best method of proceeding; and, as a great deal depended upon the success of driving through the present headings, it was strongly recommended that the safest and surest method, that of shield-tunneling, be adopted in both headings, although necessarily entailing a large expenditure in plant, and delay in time for installation. This plan met with the company's approval, and a shield and hydraulic plant were designed. As the nature of the material to be penetrated beyond the test-pipes was unknown, this shield was so made that in passing from rock to soft material, or back again to rock, it could be erected or taken apart again with a minimum of time and labor, so that it might almost be called a *portable shield*. As in both the tunnel-headings there was but one air-lock, and as it was inadvisable to remove the air-pressure from the headings, the different parts of the shield had to be of such size as could be passed through the air-lock doors. This was accomplished by dividing the shield transversely, separating the tail-end section, or that which overlaps the tunnel, from the cutting-edge section containing the working chambers. These two sections were, of course, circular, 11 feet $\frac{3}{4}$ inches outside diameter. The tail-end section was 3 feet 6 inches long, and the cutting-edge section 3 feet 8 inches long. Both of these sections were again divided, longitudinally, into four quadrants. The outside shell, in both tail-end and cutting-edge sections, was made up of one $\frac{1}{2}$ -inch and one $\frac{3}{8}$ -inch steel plates riveted together, and, at the four quadrant joints, there were $\frac{1}{2}$ -inch butt-straps 12 inches wide running the whole length of the shield and uniting the quadrants and the two sections. The middle diaphragm, separating the cutting-edge and tail-end sections, was made of two plates, one riveted to each of the two sections, and these two plates bolted together with the butt-straps united the sections.

The cutting-edge section contained two platforms, one vertical and one horizontal, of the same length as the section.

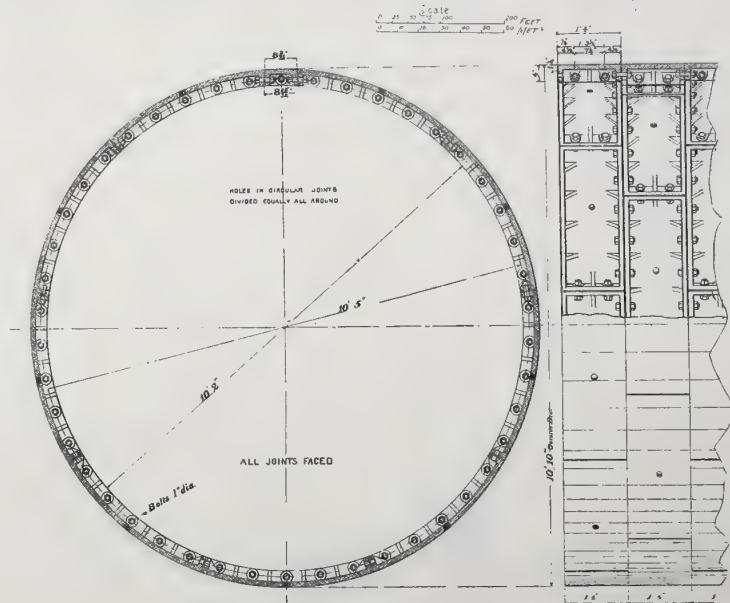




PROFILE.



HYDRAULIC SHIELD.



CAST IRON SEGMENTAL PLATES FOR LINING

To erect this shield the only riveting necessary was at the four butt-strap joints in the tail-end section, where it was necessary to preserve a flush surface on both sides of the outer shell. In the cutting-edge part countersunk bolts were used through the butt-straps. About 380 $\frac{1}{2}$ -inch bolts and 160 rivets were used to erect the shield. Two doors closing each of the four working chambers were hung on the vertical platform, and were provided with fastenings so that the whole face could be easily closed.

To drive the shield 12 5-inch hydraulic jacks were used, designed for a working pressure of 5,000 pounds per square inch, or 600 tons on the whole shield. These jacks were controlled by two block-valves, one placed on each side of the shield. Each of these block-valves consisted of six independent valves all in one compact casting, each of which had a pressure and exhaust stem. Half-inch XX pipe was used for connecting each jack with its valve, and 1-inch hydraulic pipe was used for the pressure-main which was connected with the shield block-valves by three swivel-joint connections. To furnish the pressure, a very compact little pump, designed by Watson & Stillman, of New York, was used without an accumulator, the pressure being very nicely governed by a steam-regulating valve.

On September 22d work was resumed on the New York side, with a small force of men working days only, to excavate in the rock an enlarged chamber about 15 feet back from the face, in which to erect the shield. This chamber was made circular about 15 feet in diameter and 10 feet long. Back from this, the rock was taken out in a circular form of about 11 feet diameter, for some 14 feet, or enough for about 10 rings of the cast-iron segments which were here erected in the rock, the spaces between being thoroughly grouted with Portland cement. These rings were thus made solid in the rock to withstand the thrust of the shield-jacks upon the lining. The blasting necessary in this work was made as light as possible, but it was not without its effect upon the soft material in the heading, a considerable quantity of the black mud being washed through the bulkhead, while the braces showed signs of a heavy strain from the squeezing of the material. The shield arrived at the works on November 10th, and the work of erection was immediately begun. The sections were lowered down the shaft and taken through the air-lock to the shield-chamber. On the 17th of November the shield was all assembled, and riveting the tail-end sections was commenced. For heating the rivets in the air-chamber a forge was used, with a hood to which was connected at the top, a two-inch pipe with a valve which extended through the air-lock bulkhead. By means of this pipe all the obnoxious gases from the furnace were removed from the air-chamber. After the riveting was finished, the shield was brought to its right position for line

and grade, the hydraulic jacks and valves put in place, and the necessary connections made. On the 24th of November word was received that the work on the New York side was to be pushed with all possible speed, and a force was at once organized of three gangs, working in eight-hour shifts. More rings were built on the ten rings already anchored in the rock, until the tunnel-lining was brought within the tail-end of the shield.

The shield was now advanced until it was necessary to disturb the bulkhead, the remaining bench ahead of the shield being blasted out as the shield progressed. The most difficult part of the work was now reached, for at the point where the shield entered the soft, black mud on top there still remained about 12 feet of hard rock in the bottom, as the dip of this vein was over 40° toward Long Island. Blasting had therefore to be continued in the bottom pockets of the shield after the top had entered the much softened material. As soon as the bulkhead was passed it was with great difficulty that the bottom pockets could be kept clear of the black slush from overhead. The material had become so softened along the rock face that it was almost impossible to confine it, and several rushes of inflowing material occurred, until finally an open connection with the river was established, and the tunnel was visited by crabs and mussels, together with boulders, old boots and shoes, brick, and tinware direct from the river bottom. Notwithstanding these adverse circumstances the work was still progressing, although in 45 pounds of compressed air, which was now escaping through the heading and causing a very violent ebullition on the river surface. This upward current of air held in check the downward current of water, so that no efforts were made to prevent its escape. On December 13th the shield finally cleared the rock and was now fully entered into the soft, black mud. The main difficulty now surmounted, the work progressed more rapidly, and the shield soon reached undisturbed material, which was found quite dry and hard. It was still the same black mud, with occasional lumps like charcoal, and numerous nodules of pyrites, which glistened like silver in the black peat-like mud. Mattocks were used by the men in the working chambers, who would clean out these four compartments to within a foot of the cutting edge. As soon as this was done hydraulic pressure was put upon the jacks, sometimes to the amount of 5,000 pounds per square inch, and the shield forced ahead 16 or 18 inches, enough for another ring of plates, the working chambers again being filled with the displaced material. On the 24th of December the last of the black mud was passed through, and lying next to it, at an angle of 40° towards Long Island, white decomposed feldspar was found, containing fragments of decomposed quartz charged with sulphuretted hydrogen. An important departure was now made in the method of

erecting the cast-iron lining rings by breaking joints with the segments. In all the iron-lined tunnels it has been the established custom to erect the rings with continuous horizontal joints. For some reason it was thought inadvisable to attempt breaking joints with the segments. The writer's experience in the Hudson tunnel had shown him the importance of obtaining, in soft, squeezing ground, a perfectly rigid tunnel-ring. In a material exerting hydrostatic pressure the tunnel lining is subjected to a resultant strain, tending to flatten the ring, or decrease its vertical diameter. Any yielding to this strain results both in increasing the deforming pressure and in decreasing the power of the ring to resist the strain. In a lining erected with continuous joints the rigidity of the ring is dependent upon the bolting in the horizontal joints. At the Hudson River tunnel a ring of plates were bolted together lying flat on the ground, the plates all brought to a true circle, and the two 1½-inch bolts in each joint well tightened. Upon raising this ring with a derrick, so that it stood erect, the ring was flattened three inches by its own weight. At the gas tunnel a similar experiment was made; two rings of plates were bolted together, breaking joints, one ring being revolved two holes. These two rings were then raised upright, but no flattening could be detected. By means of a turnbuckle a measured strain was now brought upon the rings along the vertical diameter. At 16,000 pounds the vertical diameter was shortened $\frac{1}{2}$ inch, the flanges of the plates cracking where the turnbuckle was attached. In these two instances there was, of course, a great difference in the size of the rings, those in the Hudson tunnel being 18 feet inside diameter, while those in the gas tunnel were only 10 feet 2 inches inside diameter. Aside from the rigidity gained, breaking joints has proved much the better plan in other ways. With continuous joints, two things are apt to occur:

First.—The joint-face where two rings meet may become slightly warped; that is, all points on this face of the ring will no longer lie in the same plane. This may be caused by carelessness in allowing dirt to get into the joints between the rings. When this once occurs the warping increases with every additional ring till true joints can no longer be made.

Second.—The rings may be erected so as to depart gradually from a true circular form. This latter case is impossible where the joints are broken, and, in the former instance, by breaking joints, the error is divided and distributed around the ring until it disappears. On January 16, 1894, the end of the soft seam was reached with the shield, and rock was again entered after having passed through 98 feet of soft ground. This rock resembled slightly the rock on Blackwell's Island. It was in a much shattered condition, with many loose heads and small, soft veins. As this material required support in the heading and a permanent

lining, and as, in its present condition, there was no assurance that it might not again pass into soft material—shield tunneling was still continued. Small machine-drills were set up in the four working chambers of the shield upon arms bolted to the vertical platform, and the rock, drilled and blasted, just ahead of the shield. The progress of 4 feet per day was made in this material, of which there was about 65 feet, the rock then becoming much more solid with a roof that was self-sustaining, arrangements were made for removing the shield. On February 18th the work of removing the shield was begun, and two days later everything was ready for the regular rock-tunnel work in the heading, the shield having been taken apart and removed in that time. At about the time that shield-tunneling was being discontinued at New York it was being installed at Long Island. An entire duplicate plant had been ordered for this side, for although it had been originally intended to use one shield for both headings, it was later deemed advisable to provide a shield for each heading, so that there might be no delay, should soft ground be met, in both headings at the same time. In passing through the soft seam at Ravenswood with the shield, no especial difficulties were met. The material proved to be a mass of soft rock fragments, boulders and cinder-like stones imbedded in soft, green chlorite. About a month was consumed in passing through this seam, removing the shield, and prolonging the cast-iron lining well into the rock on both sides of the vein. With both tunnel headings now in rock, remarkably rapid progress was made, and as progress now had become of great importance to the company, a liberal bonus, arranged on a sliding scale, was given the foremen for work done over stated amounts. Up to the time of the headings meeting an average progress of 69 feet per week was made, while in rock, on both the New York and the Long Island sides. The *record week* of the work, was the one ending June 27th, when at Ravenswood 95 feet was driven, while on the New York side, the heading was advanced 101 feet, making a total for the week of 196 feet of tunnel driven. Soon after the rock tunneling had been resumed on the New York side, this heading reached Blackwell's Island, and the troubles on this side were over. But at Ravenswood with the heading in white limestone there was every reason to expect further soft seams where the rock should change to the granitic gneiss of Blackwell's Island. These expectations were not disappointed, for after passing through 350 feet of the limestone, and when within 200 feet of Blackwell's Island, a soft seam was met, and air-pressure had to be once more used in the heading. As this seam was but 14 feet in width, and presented no especial difficulties, the tunnel was carried through it without using the shield, the cast-iron segments being erected under a timber roof. Gneiss was encountered on the other side of this soft vein,

which brought with it the assurance that the last of the soft ground had been passed. On May 16th a serious loss and delay was caused by a fire which destroyed the New York works. The fire started in an adjoining picnic ground, containing many light frame structures, which caused so fierce a conflagration that it was impossible to save our works. This caused a delay of three weeks in the time of the tunnel's completion. On July 11, 1894, the remaining 15 feet of rock between the headings was blasted away, thus opening the pioneer tunnel under the East River, two years from the time when ground was first broken. Some weeks were spent in clearing up and shutting out the water in the wet places. A three-foot gas main was now laid through to New York, and on October 15th gas was delivered into the city, accomplishing the purpose of the tunnel.

THE ABOLITION OF GRADE CROSSINGS BETWEEN RAILROADS AND HIGHWAYS.

PAPERS READ AND DISCUSSIONS HAD AT THE MEETINGS OF THE BOSTON
SOCIETY OF CIVIL ENGINEERS, SEPTEMBER 21, 1892,
AND DECEMBER 19, 1894.*

I. The Gradual Abolition of Highway Grade Crossings.

BY THE LATE AUGUSTUS W. LOCKE.

[Read September 21, 1892.†]

IN the United States, the grade crossing is now the rule, while the crossing above or below grade may properly be called the exception. And in this respect there is but little difference between city and country. In a few cities, as, for instance, in New York, Philadelphia, Baltimore and Rochester, a good deal of work has been done by way of remedy; and in Hartford, Springfield and Boston a considerable expense has been incurred, mostly applied to a few crossings, and a good beginning has been made. But, as a general thing, throughout the land the city streets cross at grade.

Literature relating to this subject seems to be scarce. It has not engaged the attention either of engineers or of the public until within a very few years. I do not know that anything was written before the year 1884. At the present time there are five American engineering reports, with the comments thereon in the engineering papers, and there are articles in the reports of the Railroad Commissioners of Massachusetts, Connecticut and New York, printed from time to time. It does not appear that English engineers have written much on the subject, or, if they have, it has not become very widely known, as I have inquired

* Manuscript received April 22, 1895.—*Secretary, Ass'n of Eng. Socs.*

† Owing to the fact that the author of this paper had entered into a contract with the publishers of a magazine to prepare one or more articles upon the subject of grade crossings, and that it was a stipulation of that contract that the information should not be used for *publication* until after the appearance of the magazine article, it has been found necessary to withhold the present paper from publication in the proceedings of the Society. The delay in the appearance of the magazine article has been occasioned, in part, by the author's death, which occurred before the articles were entirely completed.

As the publication of these articles will not occur before September, it has been thought best to print the following brief abstract from the paper in connection with the other matter now presented.—*Secretary, Boston Society of Civil Engineers.*

of a considerable number of them, including the Secretary of the Institution of Civil Engineers, of London, and have been unable to find anything.

That literature of the kind is not very plenty is shown by the fact that the descriptive Index of current engineering literature published by the Association of Engineering Societies, and covering the years from 1884 to 1891 inclusive, contains, so far as I can find, only one allusion to the subject under any head, that one allusion being to the German Report translated by Professor Swain in 1889.

In the report of the Railroad Commissioners of Massachusetts for 1884, there is a chapter on the subject, given in response to a request from the Legislature. In this chapter the subject is discussed, but no remedy is suggested. In 1887 and 1888 reports on the grade crossings in a part of the city of Buffalo were made by the Railroad Commissioners of New York and also by a Board of Engineers consisting of John Bogart, Arthur M. Wellington, George E. Mann, George W. McNulty, Walter Katté, C. W. Buchholz and Henry Flad. These reports contained recommendations as to what changes should be made, and estimates of the amount of change.

On February 1, 1889, a report was made to the Legislature of Massachusetts by a Board of three engineers, members of this Society, George A. Kimball, William O. Webber and the writer. This report set forth plans and approximate estimates for the relief of eight cities and fourteen towns, and recommended against the establishment of new grade crossings. The Board recommended that the work of abolishing existing ones should be begun on a systematic plan, and that some Board or Court should be clothed with authority to carry it out, and held that a period of forty years would be a reasonable time to allow for getting all the work done.

In the report of the Railroad Commissioners of Massachusetts for 1889, the subject was discussed at length. In this report the Commissioners discussed the means by which the danger at grade crossings may be diminished by reducing the speed of trains at unprotected crossings on branch lines, by changing the location of the highways so as to cross at right angles, by removing trees, rocks, bushes or banks which obstruct the view, by the use of electric signals and by the use of gates and flagmen, and by the arrest and punishment of any who risk their lives by crossing when gates are shut or flags displayed. The Commissioners did not approve of prohibiting new grade crossings altogether, nor did they express any opinion as to what means could be adopted for bringing about a separation of grades at existing crossings.

In their report for 1890 the Railroad Commissioners reported again on the subject, repeating their recommendations of the previous year.

The Board also strongly urged, in a general way, that the grade crossings ought to be abolished, but did not go into the subject sufficiently in detail to suggest methods of procedure.

In their annual reports the Railroad Commissioners of Connecticut and of New York have furnished information on the subject, and have discussed it from time to time.

On February 1, 1892, a report was made to the city of Worcester by a Board of Engineers consisting of three members of this Society, Mr. Charles A. Allen, Mr. John W. Ellis and the writer. This report has been printed. In it are set forth methods for abolishing all grade crossings within the city limits.

Several methods are discussed for the thickly settled part of the city, and their merits and demerits are explained, but the plan there recommended is to raise the tracks and depress the streets. For crossings in the suburbs, such plans are recommended as seemed best adapted to each locality. In this report the amount of travel on the streets and on the railroads is shown, and the interests of the people who travel on the streets and on the railroads, together with those of the railroad stockholders, are discussed. It was found that, at several crossings, the travelers along the street outnumbered the travelers along the railroad, at one point three-fold. The authors of this report recommended brick or stone arches for carrying the tracks across the street, and where, owing to lack of head-room or long span, arches were found undesirable, they recommended iron bridges with tight floors. On page 75 of this report the following statements are made with reference to bridge floors:

"The ordinary railroad bridge floor is a very unsatisfactory thing to have over a city street. The noise of trains, when passing at fast speed across such a bridge, is very annoying and frequently frightens horses. Grease from the cars and engines and from the track falls upon the street beneath. The ties and rails are apt to become very dirty in the vicinity of stations and yards where trains are accustomed to stop and where switching is done. When it rains, or when snow or ice thaws, the water, which drips from the bridge upon the street below, is apt to be dirty. Those walking upon the sidewalk can be partly protected, as is often done, by a wooden roof extending to the curb-stone, which is necessarily a somewhat uncouth and disagreeable structure, but it is impracticable to protect the people passing in the drive-way when this kind of a floor is used. The water which runs down between the tracks, along the railroad embankment, is very apt to be neglected and allowed to run down over the face of the abutment to the sidewalk and make a very disagreeable state of things. And in the winter the drippings generally freeze upon the face of the abutment and upon the

sidewalk. All of these annoyances can be avoided by the construction of brick or stone arches to carry the tracks over the city streets wherever the span and amount of available height will admit of it. At all other places iron bridges with solid water-tight concreted floors should be constructed."

The latest printed report on the subject was made to the city of Buffalo on the 9th of the present month, and was prepared by Mr. E. L. Corthell, of Chicago, and the writer. This report makes recommendations for abolishing 76 crossings, mostly by lowering the streets and raising the tracks. It deals with the peculiar state of things existing in Buffalo, where there are 500 miles of main tracks and yards within the city limits, and a very large number of crossings, said to be 300. The report deals only with the principal business part of the city. It has been recently published in the Buffalo papers.

In the Buffalo report the position is taken that the streets should be maintained at their full width, and the railroads provided with means of passing at full speed to and from their stations; that but few streets should be closed and that the present ruling grades for streets in the various sections of the city should not be increased. Three per cent, was recommended as a maximum, that being the heaviest now existing in the vicinity. Nearly the whole of the area under consideration is less than 18 feet in elevation above the ordinary level of Lake Erie. The report recommends a head-room of 20 feet over tracks, and from 12½ to 15 feet over streets. In 18 months, 61 travelers, on these streets, were killed while attempting to cross the tracks.

The first work done in the city will often determine the system upon which subsequent work must be carried out. For instance, if one important street is carried under the railroad without changing the tracks, the tendency is to carry the other streets in the vicinity under in the same way, because (1) in such a case the tracks cannot be lowered much without throwing away the work already done, (2) it would not be well to lower one street and raise another in its immediate vicinity, and (3) it would probably be said that if one street has been depressed to a certain grade the others could also be depressed to the same grade. It will generally be found most advantageous, to the railroad and to the cities, to have a full plan decided upon before going to work, in order that all interests may be considered together—the station, the bulk tracks and the private sidings, as well as the streets.

Where sidings are not too numerous it will sometimes be found to be cheapest to raise or lower the tracks, rather than to confine the change altogether to the streets. In cities, the latter plan is apt to entail large expenses for damage done to adjoining estates, while, as a general thing, damages for changes in the grade of the railroad cannot

be recovered by adjoining owners. A wise provision in our laws calls for a clearance of 18 feet above the rails, and, if any change were to be made from this figure, it would probably be increased, as the tendency is to increase the heights of all cars. Measurements recently made in the city of Buffalo showed that there were running into the city, freight cars measuring 14.2 feet from the rail to the top of the running-board, and others 14.8 feet to the top of the brake wheel, while on the Michigan Central Railroad cars were allowed to be loaded to a height of 15 feet 4 inches. Continuous air brakes on all freight trains, much as they are to be desired, do not seem to be within our reach at present, and it may be doubtful whether it will not for many years be necessary for men to be on the tops of freight cars and to use hand brakes in and about freight cars and stations. So I am unable to see any practicable way to avoid raising the streets, where it becomes necessary to raise them, to the full height required by the present law of this State, or, it may be, even higher, as is now required on various railroads in the West. And, of course, every extra foot of height in such cases adds very largely to the expense of the work and to the damage.

While the necessity of the abolition of the crossings will probably not be seriously questioned here, it will, on the other hand, be granted that the expense would be very great, and the question naturally arises whether the community can afford it. The public at large will finally have all the bills to pay. The expense may be brought upon the railroads somewhat uniformly, so that no one road shall be given a great advantage over the others, but if it should increase the cost of transportation by increasing the fixed charges, or if it should prevent the rates from being lowered as they have heretofore been lowered from year to year, whatever burden should arise, it would have to be borne by the people at large, for whom the railroads do business. The English have been able to afford these improvements from the very beginning of their railroad system; we are richer to-day, and our wealth per individual is greater. In communities like the State of Massachusetts, the inhabitants have advanced in wealth far beyond the necessity of confining themselves continuously to getting food and protection from the weather. They are in condition to have many things which a settler in a new country would not expect. We seem to afford elegant stations, and cars which cost a small fortune apiece, and probably we shall afford to have the crossings abolished gradually as the opportunity presents itself.

The passenger stations also demand some attention in considering this question. Some of our passenger stations are among our very worst and most dangerous grade crossings. On some of our double track roads there is no restraint whatever. Persons pass back and forth across the

tracks at will, boys play on the tracks in front of fast express trains passengers have to cross the tracks to reach their trains. Important stations are often placed at a highway grade crossing, and the greatest care, on the part of the gate-keeper and the enginemen, will not prevent accidents. The English stations are far superior to most of ours in this respect. Their express trains run at full speed through stations where a large business is done; and there is seldom any reduction of speed except where the train is due to stop. The ability to do this in safety is obtained only by keeping the people out of the way. Bridges, or subways, are used for passing from one side of the station to the other, and the passenger, when entering a station where through trains pass, shows his ticket and goes to the proper stairway, which takes him to the platform from which his train will start. We have a very few stations arranged somewhat after this manner.

I know it is sometimes said that our gates are good enough, that they indicate to the people that trains are approaching, and that it is the duty of all to take warning; that level passenger stations, with no way of access to half the trains except by crossing tracks in front of the other half, or by going through them, are all right if people will only exercise care. But I would like to be understood as disagreeing entirely with that theory. The time and energy of the people ought to be directed to other matters than watching for their lives when traveling on the highway, or when taking trains at stations, especially so when well-known remedies are within reach.

And it should further be borne in mind that there is one portion of our population, the children, who are not supposed to be able to exercise the constant vigilance and care of which older persons are capable. They have to pass along the highway, to school and elsewhere, alone. Who is to look after them?

II. Abolition of Grade Crossings.

BY JAMES W. ROLLINS, JR., MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read December 19, 1894.]

IN the early days of railroading in this State, from 1830 to 1850, when railroads were new, money scarce, and the public eager to get better facilities for commerce and travel, the main question at issue was, *how* to get the railroads built, and not in what manner and under what restrictions shall they be built.

Two or three trains a day sufficed to accommodate both freight and passengers, and the crossing of the highways, not so numerous then as

now, must have afforded the natives a good and welcome chance of seeing the engine and cars as they went by.

Grade crossings then must have been popular, for the cheapness of their construction saved the railroad companies much money, while their use saved the public much labor, both of man and beast, in climbing up and down in order to pass over or under bridges.

So the grade crossings came, thousands of them, and not until the last twenty years has public opinion been turned against them.

In justification of the early methods of railroad construction in which grade crossings were considered to be not an evil, but often a necessity, the Railroad Commission has several times expressed its opinion. In 1889, it said :

“It is unnecessary to go into a careful examination of the law in regard to the establishment of grade crossings at different periods in the history of our railroads. For the purpose of the present inquiry it may be presumed that the existing grade crossings have been created under the authority of the Legislature, and subject to such limitations as it has from time to time seen fit to impose.

“When the main lines of the railroads were built in this State, the problem was a somewhat different one from that which presented itself in England and on the Continent.

“There the districts through which the railroads were to run were comparatively thickly settled. There was greater immediate necessity for avoiding grade crossings, and the prospective earnings of the roads were such as to justify a larger expenditure than could have been profitably incurred in a district such as the interior of our State was from forty to sixty years ago. After the feasibility of the transportation of passengers and freight by railroad was demonstrated, the next question was, whether it would pay, and, in determining this question, the original cost of construction was a most important item. It is probable that the building of our roads, and the consequent growth and prosperity of our State, would have been retarded many years if the Legislature, in the infancy of railroads, foreseeing the difficulties which now beset us, had legislated for the benefit of this generation rather than for their own.

“In considering the evils attendant upon grade crossings, and the means of avoiding them, it must, therefore, be borne in mind that the existence of grade crossings is not due, as a rule, to any blindness on the part of the railroad corporations, much less to any intentional fault of theirs, but rather to circumstances which they could not control, and which are appreciated by the public; so that the existing grade crossings not only were created by the authority of, and with the sanction of, the Legislature, but, generally, were also created in accordance with the wishes of the vicinage.

"The history of the creation of grade crossings fifty years ago has its counterpart to-day when the building of a new road is proposed. The profitableness of the road is generally questionable. It is projected to furnish facilities to a promising district, in the hope that it will develop the district. Frequently the stock of the company is subscribed for by the people along the proposed route ; and these people, being anxious that the actual cost of their road should be as low as possible, are the very ones who pray for grade crossings—urging, with facts to back them, that the road cannot be built if grade crossings are not permitted.

"Even those people, living along the line, who are not subscribers to the stock, in their gratification at the prospect of railroad facilities, heartily second any efforts on the part of the corporation to secure permission for crossings at grade."

The report of 1880 contained this expression in regard to grade crossings: "All men conversant with railroads deprecate the increase, and even the existence of these nuisances; and, in general, the community agrees with them, but, in each special application, a different feeling is shown. Then the expense of an overhead crossing by the highway, with the unsightliness of the structure and the wear of horse-flesh, or the inconvenience of a depressed way with its injury to adjoining property, is urged against all considerations of safety. Each citizen is confident that no accident will happen to him, or to his family; while many residents in the locality interested, fear some immediate injury from any other mode of crossing than at grade."

The public seems now to take this position: that when the railroads were built, they should have avoided these grade crossings and built bridges, and, as they chose to do differently then, they must now correct their errors and spend millions thereby.

In fact, it sometimes seems as if public opinion opposed these crossings, merely because corporations made them, and not on account of any warrantable objection to them, based on facts.

No one denies that grade crossings are dangerous—particularly to those who do not look out for their own lives.

From 1879 to 1889, the average number of persons killed and injured on the 2,000 odd crossings in the State was 43, of whom 22 were hurt at protected crossings, and therefore, presumably, on account of their own carelessness.

In 1893, on 2,216 crossings, 993 of which were protected, 76 persons were killed and injured; 36 at protected, and 40 at unprotected crossings.

The consistency of our Legislature and of the public does not appear to advantage in their treatment of the general question of grade crossings.

The former pass laws, involving the State in an expenditure of \$5,000,000, to abolish grade crossings, and then grant charters, indefi-

nately, to electric car companies who pay nothing for their location, and who, in their crossings at grade with steam roads, create a danger far greater than ever before existed.

Comparing the statistics of accidents on electric roads with those at grade crossings on steam roads, we find, that in the year 1893, as stated, 76 persons were killed or injured on steam roads, while, in the year ending September 30, 1893, there were 595 persons killed or injured by electric cars on public highways.

In the electric railway construction of to-day, history, with all the faults and short-sightedness of the past staring it full in the face, is repeating itself, with the certain knowledge that before long another overturning of things, including public opinion, must come, and that the public highways must be kept clear of everything which endangers the lives of those who travel thereon, either on foot or in vehicles. At the present time the public wants electric railways, and is willing to do anything, to run any risk, to get them; and it will, in so doing, impose upon coming generations just such a burden as has been imposed upon us by these thousands of grade crossings made years ago.

But the crusade has begun—grade crossings are going, electric and other wires are being buried, and the beginning of a return by the public to common sense and consistency in the matter of electric cars has been made, and one step toward the desired end, the prohibition of a grade crossing of an electric railroad with a steam road, is being urged by the public and the press, and to such an extent that it is to be hoped our coming Legislature will pass laws, regarding electric roads, in accordance with those already existing and controlling steam roads, the construction of which is surrounded with all sorts of safeguards for the public.

The selectmen of a town, or the mayor and aldermen of a city, must approve their location, and this, in turn, must be passed upon by the county and railroad commissioners, while, for an electric road, the permission of the selectmen or aldermen only is necessary, even though the proposed location creates a grade crossing with a steam road.

Legislation against grade crossings began in 1849, when a commission was appointed to consider the crossings at the northern part of the city of Boston. This applied to crossings of railroads with each other, highways then not being considered.

Prior to 1872 the law contemplated that railroads should pay the whole cost of the abolition of grade crossings, but in that year provision was made for an equitable apportionment of the expense between the railroads, on the one hand, and the cities, towns and counties on the other. This law provided, however, for action only where all parties in interest could agree, and left the apportionment to a commission of three men—one representing the town or city, one the railroad, and the third a member of the Board of Railroad Commissioners.

In 1876 the Legislature passed a law requiring the consent, in writing, of the Railroad Commission to a crossing at grade of a railroad and highway in addition to the authority of the County Commissioners.

Since then, however, many new crossings have been made, and the Commission, while generally opposing them, have, in certain special cases, approved of them and allowed their construction.

In 1881-82 numerous crossings were granted to the Massachusetts Central Railroad in Waltham and Belmont, the almost universal sentiment of the citizens of these towns being in favor of such construction.

Our legislators seem to be always ready to frame and pass laws for the general benefit of the Commonwealth, but also equally ready in special cases, where facts and conditions may seem to warrant them, to pass others which render the general laws null and void, the present only being considered. In compliance with the general laws and public opinion, the Railroad Commission has for many years been strongly opposed to grade crossings, sometimes refusing to allow them, even if such a refusal might "imperil the whole undertaking;" while again, in other cases, it offers this same reason, together with others good and sufficient, as their ground for granting such crossings.

These special laws of the Legislature are often the means and reason of such permission, the Commission taking the ground that the Legislature, having granted to a company a charter to build a road upon which it is evident that grade crossings must be created, the Commission can but give its consent, on the best conditions obtainable and under such restrictions as may be enforced.

As late as 1893 five grade crossings were granted to the Southbridge, Sturbridge and Brookfield Railroad, because, it is understood, of such provisions of their charter as made it impossible for the Railroad Commissioners to act differently.

Two different opinions of the Board are as follows.

In 1890 the Board reported:

"During the past year the Board was called upon to approve—and it did approve—of nine grade crossings for the Grafton and Upton road. The community desired that the road should be built. It would not have been built had not grade crossings been permitted. The Board did not feel justified, in consequence of the slight danger incurred at such crossings at grade, in refusing its approval, thereby depriving the community of the railroad facilities which it much desired."

In 1892, upon request of the Plymouth and Middleborough Railroad for a grade crossing in the town of Middleborough, the Board made this report:

"Upon an examination of the premises the Board refused to give its assent to a crossing of Plymouth Street at grade. This street is

crossed by a proposed line of the railroad at an acute angle, being an angle less than forty-five degrees, and the estimated expense of avoiding a grade crossing was twelve thousand dollars. This expense could, however, be diminished considerably by changing the location of Plymouth Street, so that it should be crossed by a railroad more nearly at a right angle. It was urged, with great earnestness, that the refusal of the Board to assent to a grade crossing on this street would so increase the cost of building the railroad, that the success of the enterprise would be imperilled. The conditions of the case, however, did not seem to be such as to justify granting the petitioners' prayer."

The Legislature, in 1884, passed this resolution :

Resolved, "That the Railroad Commission examine and report to the next Legislature, upon the subject of providing for the gradual abolition of grade crossings in cities and the populous parts of towns."

In accordance with this resolution the Board reported, in part, as follows :

"It is believed that \$100,000,000 would be the cost of abolishing the crossings included in the resolve of 1884—amounting to 80 per cent. of the existing capital stock of our railroad companies. This work, if done in a period of 10 years, would call for an annual expenditure of \$10,000,000, and for a general suspension of dividends for that period at least.

"It should not be forgotten that every one of the crossings was made under authority of law, and by direction or permission of the tribunals appointed to decide for or against such crossings. In some cases a statute of the Commonwealth specially ordered this mode of construction.

"In some other cases, the company desired to avoid the dangers of a grade crossing, but was, at the instance of the town authorities, compelled to construct its road at a level with the highway.

"The expense of a change would be far greater than the cost of original construction over or under the highways. In many cases another route would have been chosen, by which the crossings would have been avoided, but for the favorable decision."

In 1888, the Legislature passed a resolve, that the Governor should appoint a Commission of three competent and experienced engineers, to investigate and report upon the subject of the gradual abolition of grade crossings, with recommendations as to the method of apportioning the expense of such work.

This Commission made a careful examination of the whole subject, and an exhaustive report, with estimates on the cost of the abolition of all the grade crossings in the State.

The result of this was the Grade Crossing law of 1890, with which

you all are probably familiar and under which the railroad pays 65 per cent. of the cost, and the State and the town or city the balance, the latter paying not more than 10 per cent. in any case.

Assuming this estimate of the Board, of \$100,000,000, to be approximately correct, the railroads, under the law of 1890, would pay, as their share of the expense, \$65,000,000, provided the conditions of the act were to be continued, after the \$5,000,000, which *it* fixed as the limit of the State's interest, had been spent, and until all the grade crossings were abolished.

Of the 2,165 crossings in the State, about 1,000 are protected, at an approximate cost of \$500.00 each, or a total of \$500,000, per year.

This amount, capitalized at 4 per cent., gives \$12,500,000 as the amount which the railroad companies can spend on crossings without loss. In addition to this cost of protection should be added the amount paid by the railroad company on account of accidents at these crossings. Of this I can find no data. The money spent in excess of the above aggregate, deducted from the 65 per cent. which the railroad company pays, is absolutely sunk by the railroad company, and no returns come from it. When all the crossings in the State are considered, it looks far better for the railroad company than when some individual crossing, or some group of them, is taken; as, for instance, on the Providence Division, where twelve crossings are abolished at an expense of probably three and a half millions of dollars, or nearly \$300,000 for each one. The cost of protecting these crossings is probably \$20,000 a year, or \$500,000 capitalized. I do not think that the payment on account of accidents on these crossings has been anything of account for many years—so that the balance of the cost to the railroad, 55 per cent. of \$3,500,000, or \$1,925,000, less \$500,000, or \$1,425,000 goes into work from which the company gets no return from additional passenger or freight receipts, and for which they pay annually, at 4 per cent., \$57,000.

On the Old Colony System, there are now under way, or before commissioners, four schemes, which will cost over \$6,000,000.

These schemes are Providence Division, Chickering to Mt. Hope, Dorchester Avenue and Dover Street, Boston, and at Brockton. In addition to this, Fall River, Taunton, New Bedford, Attleboro and Clinton, and I do not know how many more towns or cities, have begun, or are contemplating beginning, action for the abolition of their grade crossings, which would probably cost \$5,000,000 more. That is \$11,000,000 or more is to be spent on crossings, \$7,150,000 of which must be paid by the railroad company, while the entire capital stock of the Old Colony Railroad is only \$14,000,000.

Do you wonder that the railroad companies go slowly in their approval of these schemes, and that they ask where the money is to

come from to pay for them? It all comes from the public, and the public still clamors for lower rates of fare or of freight, and, on the other hand, better facilities in every way, and to crown all, the expenditure of millions to abolish these grade crossings, which originally were built to the satisfaction of the public and in accordance with all the conditions then existing.

The liberal policy of our State, in putting one-third the burden of this enormous expenditure upon the city or town and the State combined—will go a long way towards making possible these improvements, which otherwise would have been delayed, with the result of a great increase in the ultimate expense.

Under the provisions of the law of 1890 the Commission decides whether the *safety* and *convenience* of the public require the separation of grades. Having decided that the separation of grades *is* necessary, the *safety* of the public is assured, and the problem in hand then, is to provide for their *convenience*.

This means, generally, to make as little additional labor as possible for the public—to avoid obliging it to go farther out of its way, either vertically or horizontally, than necessary.

This problem of adjustment of the grades of railroads and streets, especially through a city, is the most difficult part of the problem.

The question of clearance for the highways, the amount the street is to be lowered or raised, the grade necessary to accomplish these results—all these must have due consideration.

In regard to the question of clearance, I must differ from some of you who have charge of the engineering of cities.

Many years of interested observation have led me to believe that the cases of street loads which require a clearance of more than fourteen feet are extremely rare, and that no necessity exists for such extreme loads; such, for instance, as pile-drivers, empty barrels or loads of furniture, with long-legged stools tied on top of a load already high.

When it is a question of whether the whole traveling public on the railroad must climb one or two feet of additional steps, and every ton of freight, cars, engines and all must be raised that additional height, or provision made for such sky-scraping loads, it seems to me a most absurd condition, and a "balance sheet" which is not generally made by our engineers in these days of careful examinations, and actions according to the result of such examinations.

Take the Providence Division of the Old Colony Railroad, for example. From the Roxbury, Heath, Boylston, Jamaica Plains and Forest Hills stations are now carried 2,225,000 passengers annually.

Over 50,000 trains run over this piece of track every twelve months, carrying 1,500,000 tons; so that each foot of additional rise of track

means that these 2,225,000 of passengers must raise or lower themselves that additional foot—and 1,500,000 tons be raised the same distance—in order to let, possibly, 1,000 teams through the bridges, rather than delay a couple of men ten minutes to readjust their load to a reasonable height, or 167 hours of time at \$1.00 an hour for men and team, amounting to \$167.00 a year. Who of you, gentlemen, would travel up 2,225,000 steps of one foot, or 450 miles, for \$167.00?

Multiply this even by ten and still the difference is enormous.

And again, most of our main highways are parallel to the railroads radiating from the center of the city, and the great bulk of the teaming does not cross the railroads at all. A teamster, having been caught once with a high load, will not be caught a second time, and thus all will be adjusted in a year or two.

On the other hand, from now to eternity, or until electricity or flying machines have rendered our railroads useless, this great waste of human and mechanical energy must go on.

My judgment on such questions is that the great consideration is the convenience of the *public*—not that of the *few*—and the railroad traveling public is the one whose interests are the greatest in a locality such as those mentioned. Hence the less the railroad need be raised the better.

This is generally admitted, and plans are made accordingly, but in such plans the demand of the cities for high clearance often brings an enormous burden upon the patrons of the road and upon the railroad company for increased construction, and all this for the benefit of a very few persons who could, if they would—and would, if obliged—regulate their business to conform with that condition which the greatest good for the greatest number demands.

III. Abolition of Grade Crossings in the City of Brockton.

(a) PRELIMINARY NEGOTIATIONS.

BY F. HERBERT SNOW, CITY ENGINEER OF BROCKTON.

[Read September 21, 1892.*]

THE city of Brockton is a rapidly growing shoe-manufacturing town of some thirty thousand inhabitants. Its area of twenty square miles is rectangular in shape, approaching that of a square, through

* This paper was presented in the discussion of the opening paper of this series, on The Gradual Abolition of Highway Grade Crossings, by the late Mr. Augustus W. Locke.—*Secretary, Boston Society of Civil Engineers.*

the geographical and business center of which the central division of the Old Colony Railroad runs in a southerly direction. From the town of Avon on the north, to the town of West Bridgewater on the south, there are three passenger stations, named, in order, Montello, Brockton, and Campello.

The station at Montello was built some six years ago, and is of sufficient size to accommodate this part of the town for the next ten years. The facilities of the passenger stations at Brockton and Campello, however, have for a long time been totally inadequate. In the spring of 1891 the directors of the Old Colony Railroad decided to erect a new passenger station at Brockton, and also a new freight depot. Plans were gotten out for the same, and a description given to the public through the Brockton *Daily Enterprise*. The design of this station was perfectly satisfactory. The Company's plan, however, was to locate this beautiful structure on a level with the existing grade of the tracks, which would thus effectually stop any movement towards the abolition of grade crossings—of which there are five in the immediate vicinity. Because the larger part of the city is on the west side of the railroad, while all freight has to be shipped and received on the east side of the railroad, these crossings are continually in use. The railroad company has no freight yard proper, and it therefore switches its trains through the city on the main and side-tracks, thus obliging the public to cross a veritable elongated freight yard.

This has become a serious matter. Many times the apparatus of the fire department has come flying down some one of the five streets in response to an alarm from the East Side, and has been brought to a standstill to wait for a long freight train to switch back and forth.

These conditions cause much delay and injury to business. On this account, insurance rates are higher, and land values and rents lower, on one side of the railroad than on the other. These facts, and the importance of these crossings in relation to the city's future, have caused the growth of an objection to their existence at grade. This objection, which is by no means a sentimental one, has manifested its disapproval of the Company's plans, in the form of a petition to the City Council that the Board of Mayor and Aldermen apply to the Superior Court for the appointment of a Commission, under the Grade Crossing Act of 1890, to consider the necessity of the abolition of all grade crossings in the city of Brockton. After this request had been complied with, those citizens whose property abutted on the railroad and on the streets where changes might have to be made, began to speculate as to the manner in which this stupendous undertaking could be carried out with the least injury to their private interests.

That a clear understanding of the case may be had, I will state

that manufacturers have found it advantageous to locate their shops along the line of the railroad and within about one quarter of a mile of it, so that the city has by degrees stretched out over a territory unusually long for that of a manufacturing center. For three miles along the railroad, thousands of dollars have been invested in improvements and facilities for doing business with the railroad. Side-tracks are numerous, and not a few concerns are dependent upon these for their prosperity.

To make the problem one of greater concern to private interests, Montello Street, a business thoroughfare, runs parallel to, and about 130 feet from the railroad, through the entire length of the town, and upon this street, in the neighborhood of the five principal crossings, are situated brick buildings, hotels, factories, an electric light plant, gas plant and many wooden structures. To disturb the grade of this street to any extent, would involve the city in hopeless litigation. The remonstrance to such a plan would be greater than the desire for a riddance of the grade crossings.

The more abutters sought for a satisfactory solution of the problem, the more fearful they became of the results of the damages that their property might sustain. Naturally these people, in their dilemma, looked to the Mayor of the city for assistance, as did the general public, whose suspicions that the Old Colony Railroad would not look out for Brockton's welfare except in so far as was consistent with that company's ends, had been aroused by the company's plan to perpetuate the existence of the present street crossings at grade.

Finally, the city engineer was directed to prepare and present to the Board of Aldermen, for their approval, a plan for the abolition of all grade crossings in Brockton. Preliminary plans were made. Briefly, these called for the elevation of the railroad and a depression of the streets through the center of the town, and a depression of the railroad and elevation of the streets at Campello. The plan would necessitate the abandonment of the present passenger stations and freight depots at Brockton and Campello and the construction of new ones on different sites. The passenger station at Campello, however, could be kept on the present lot, provided more land was obtained.

In order to render feasible the elevation of the railroad through the center, some eighteen acres of land, intended for use as a new freight yard, would have to be elevated from six to fourteen feet. The grade of the main tracks to the yard would then be not less than one per cent. After due consideration, this plan was adopted by the Board of Aldermen.

I believe that it is folly for a community like Brockton to attempt to force upon a powerful railroad corporation the expenditure of a mil-

lion dollars or more, no matter how great the demand for the separation of the grades of the railroad and the highways. The Directors will not be forced to make a change until they are ready to take up the work, and then the improvement must be in accord with their ideas of what is practicable.

The Mayor and Aldermen had come to a firm decision that the plan adopted by them was the only plan that would not work to the permanent disadvantage and disfigurement of the city. It was very doubtful whether or not the railroad company would see it in this light, when other plans could be designed that would not call for such radical changes in its property. Either the directors must be brought to see that their interests and those of the city were identical, or nothing could be accomplished. This task was undertaken by the Mayor, Hon. Ziba C. Keith. His arguments convinced the company that it would be easier and cheaper to abolish immediately Brockton's grade crossings rather than to wait until the city became larger.

The question then arose as to how the separation of grades might be effected, and the city's plans were submitted to the president. Finally, an agreement in writing was made, accepting the city's plans and fixing the new elevation of certain highways at the railroad, and the number of feet of "head room" required.

Upon the strength of this agreement, the railroad company and the city joined hands in securing a special legislative act relating to private crossings in Brockton. This mutual understanding has brought together, officially, the chief engineer of the railroad company and the engineer of the city, under conditions calculated to secure the very best results. This is as it should be. Who knows, so well as the city engineer, what is feasible in changing grades and lines of streets, sewers, drains, gas, water and electric wire pipes, and a thousand other things none the less important because of their number?

What railroad engineer would, unassisted, hope to devise any plan which would not be bitterly opposed by the city engineer? On the other hand: What city engineer wishes, or is competent, to dictate to the railroad engineer?

It was decided that the engineers prepare, jointly, a separate plan for each crossing, that these plans should be signed by them, approved by the President of the Company and by the Mayor of the city, and presented, with the specifications, to the Commissioners.

The advantages of this method I have not time to discuss, but I think it must be at once apparent that there is no disadvantage.

I wish to explain carefully our method of dealing with the problem of damages, which I am confident will be of more than passing interest to you. Under the pleasant conditions spoken of, it has been possible to

carry out an idea advanced by Mr. George A. Kimball, who has been associated with me as consulting engineer.

Three disinterested, competent men were appointed by the Mayor to appraise the property and estimate damages to each and every estate to be affected. A book was prepared for each appraiser. It contained a description of every estate and the alterations to be made. Blank spaces were left for amounts to be carried out, also for any necessary remarks. These men were expected to view each estate and to estimate just awards, independently of each other.

Under the direction of the City Solicitor and Clerk, several blank forms of agreement, worded to suit different cases, were drawn up and copies of each were printed.

In general, they were propositions to the City of Brockton, as follows :

“Whereas, under the provisions of Chapter 428 of the Acts of 1890, the same being entitled an act to promote the abolition of Grade Crossings, it becomes necessary to enter upon, and take from me a certain parcel of land, and to make certain changes in grade in front of my estate in connection with the abolition of the grade crossings of the Old Colony Railroad Company, at ——— Street, in the City of Brockton, County of Plymouth, State of Massachusetts; and whereas, the changes in line and grade of said street and approaches thereto, as shown on a plan for the abolition of said grade crossings, dated ———, are necessary for said abolition, I, the undersigned, owner of, or having interest in, real estate adjoining said portion of way, do hereby agree that I will accept the sum of ——— dollars, in full settlement and satisfaction of any and all claims for damages I have or may have against said City or other corporation on account of such taking of my lands, or on account of such changes of grades.”

With the appraisers' estimates to refer to, abutters have been approached and requested to come to an agreement in regard to damages.

Thus far we have not failed to show to abutters that it is for their interest to make propositions of settlement. We state frankly that our interest in the matter of settlement is to know definitely what the cost of the work is to be, and that the item of damage is a large one in this amount.

In closing, I wish to express my opinion that the proper authorities of cities of the Commonwealth of Massachusetts should take the initiatory steps in the abolition of grade crossings within their respective districts.

By initiatory steps I mean not simply to submit a petition to the Superior Court for the appointment of a commission. Such a commission may consist of men not civil engineers. There is no doubt that such men as would be nominated by the State, the railroad company

and the City, each of which has its representative on the Commission, would be fully competent to determine whether or not the changes called for were a public necessity. No doubt three Commissioners might be appointed who could solve all problems attending the separation of grades of a railroad and the highways of a populous community, and adjust and fix the manner and limits of such a separation to the satisfaction of all concerned.

While such a result is possible, I believe it is extremely improbable. Under the present act, the security of the public rests entirely in the decree of the Commission, which is final. If changes are made, and if they are not satisfactory in construction or otherwise, there is no possible redress. The commission ends with the decree. If the city authorities do not like what is done, they can change it at their own expense. The decree should be right at first, and, therefore, when I say initiatory steps, I mean those steps necessary to secure protection in this respect.

I believe that a city seeking a just settlement of a grade crossing problem can secure the best results by placing the matter in the hands of a commission consisting of the city engineer and the railroad engineer, and one other appointed by them. If the report of these experts is satisfactory, and if their plan is finally adopted by the Special Commission appointed by the Court, the decree of the latter should contain verbatim the detailed specifications prepared by the former. By this method, I can hope to see satisfactory changes made in crossings at grade of city highways and railroads, and by this method only can I hope to see the positive security of the vital interests of a community which alone warrants procedure in so important a public work.

(b) THE PLANS ADOPTED.

BY JAMES W. ROLLINS, JR., ENGINEER FOR THE OLD COLONY R. R. CO.

[Read December 19, 1894.]

MUCH of the following is taken from an article prepared by the present writer for the *Railroad Gazette* and published in that journal early in 1894.

Brockton is a city of about 30,000 inhabitants, on the main line of the Central Division of the Old Colony Railroad. The growth of the city has been one of the largest among Massachusetts towns: a town in 1821, a city in 1881, and increasing from 13,000 inhabitants in 1880 to 30,000 at the present time, as above stated. Within the city limits are three stations, with freight yards and houses—Montello, Brockton and Campello. As in most manufacturing towns, the growth has been along

the line of the railroad ; gradually streets have been laid out across its tracks, all at grade ; and private ways and farm crossings have become public ways, so that at the present time there are eleven crossings at grade over which the public have rights. The freight yard at Brockton is at present in the center of the city and freight cars have to be shifted across the principal streets.

When the grade crossing law was passed, in 1890, Brockton was the first city to avail herself of it, and immediately petitioned for a commission to be appointed in accordance with the provisions of the act and also began negotiations with the railroad officials regarding the abolition of all the grade crossings within the city limits. The act of 1890 provided only for public streets, and, as many of the most important streets in Brockton had never been accepted as public ways, a special act was passed in 1892 permitting the Commission to consider private ways. Various schemes were presented and discussed, and finally an agreement was made between the city and the railroad, in June, 1893, to raise the grade of the railroad through the center of the city 12 feet and to depress it through Campello about 8 feet.

One of the worst complications was the question of freight facilities at Brockton. A short time before, the railroad company had bought a piece of land of about 15 acres for a freight yard. This land is some 15 feet below the grade of the tracks as they now are, and to get down into this yard from a grade 12 feet higher necessitated raising the whole yard some 10 feet, and building, across the main streets, switching tracks supported by heavy retaining walls.

While the affairs incident to the change of management from the Old Colony to the New York, New Haven & Hartford were being straightened out, the plans described above were changed, and entrance to this freight yard, to which had been added some 20 acres more of land, was made from the north side at a great benefit to the yard, and great saving of expense in extra tracks and walls through the city. These plans, now adopted, call for the following changes and work :

The grade of the railroad is to be raised, for a distance of 9,000 feet, the maximum rise being 15 feet, and lowered for a distance of 5,100 feet, the maximum being 12 feet. Four tracks are to be built throughout the length of this change of grade ; new passenger stations are to be built at Brockton and Campello, and a new waiting station at Montello, all from plans of Bradford L. Gilbert, of New York City, who has made the plans for most of the recent stations on the Old Colony road.

All stations will be double, consisting of a main station on the west side of the tracks (trains run toward Boston on the west track), with a waiting station on the east side. Subways under the tracks

connect the two. The Brockton main station will be 33 feet by 140 feet, and the waiting station 30 feet by 104 feet. This main station will be on the grade of the tracks, and the approaches will be graded to it, so that carriages can drive up to the platforms. A walk leads from the main street to the subway, which continues through under the station and tracks, on a level, to the waiting station on the east side. All the stations are to be built of granite, with red sandstone trimmings.

At Campello, which is the terminal for a series of local trains, the present terminal grounds, with engine-house, turntable and coal sheds, will be taken and used for the new passenger-station grounds, and a new terminal will be provided, about 1,500 feet south of the present one. For this terminal a tract of land of about seven acres will be taken, admirably fitted for such a purpose. It is dry and has a gravelly soil, which can be easily drained. On this will be built a 70-foot brick engine-house with four stalls, a 60-foot iron turntable and a coaling trestle, with all necessary tracks, sidings and connections.

This change of grade, as decided upon, will require the construction of seven arches of masonry over streets, two arches over streams, four subways for pedestrians, three of which are between stations, as before described, two plate-girder bridges, also over streets, and eight highway bridges over the railroad.

Three of the street arches have a span of 50 feet, with rises of 7, 8 and $9\frac{1}{2}$ feet respectively, and two with spans of 41.25 feet, with rises of $6\frac{1}{2}$, and 7 feet; the other two arches are 30-foot spans, practically semicircular. All arches, except the two latter, have walls 7 feet high above the sidewalk, at the ends of the arches. To overcome the difficulty and expense of these flat arches, the arch sheeting, with the exception of about 3 feet at each end of the arch, is continued down to skewbacks almost at the street level, so changing the ratio of span to rise in the worst case from 7 to 1 down to about 5 to 1. This changes the angle of the resultant of the combined loads so as to bring it within the middle third of the foundations, designed to carry a load of 3 tons per square foot, which is the limit allowed for these structures, the soil being good, firm gravel, and the masonry foundation 4 feet of concrete. The faces of these arches will show an arch springing from a skewback, 7 feet above the street grade and on the street line, but this skewback and wall supporting it will be only 3 or 4 feet thick, and then the arch will drop back as stated. It is proposed to build an ornamental iron fence on the line of the walls, *i.e.*, the street line, on a heavy curbstone, to keep the public within the street limits.

The backing of all the arches will be of concrete; and to make this water-tight it is proposed to cover this backing with three thicknesses of heavy roofing paper, each lapped one foot and thoroughly tarred over,

with an inch of asphalt over the paper. The water will be collected in gutters to be built in the edges of the concrete backing, and from them conducted through the masonry by pipes into the street drains. Only two of the five main arches are square, the balance being at angles varying from 83 degrees to 57 degrees. It is proposed to make the ring stones of these arches of granite, in courses parallel to the axis of the arch, with the faces cut on the skew required, with possibly the exception of the worst angle, which may be built with a true skew face with arch inside of brick.

Plate-girder bridges will be built to span Ashland and Lawrence streets, the former requiring girders 57.5 feet long, and the latter girders 47.5 feet in length. These bridges will be built of wrought iron, with floor beams, supporting track stringers, which are spaced 6 feet apart on centers. On these stringers will be the floor, of 8 x 8 inch ties, 13 feet long, spaced 4 inches apart, and guard-rails of 8 x 8 inch timber, notched to 6 inches outside of track, and rail-guards inside of track. These bridges are to have a plank floor on the ties, to protect the travel in the street below.

All masonry supporting track bridges is to be of first-class ashlar. Highway bridges will be riveted lattice trusses, with suspended floor beams between tracks. Trusses will be about $7\frac{3}{4}$ feet in height for 70 feet spans, or generally about one-ninth of span, and will carry a sidewalk on both sides of the roadway. The floor of the roadway is of double planking, 3-inch hard pine underneath, on 4 x 14 inch hard pine floor stringers, and 2-inch spruce planking on top, forming surface of roadway. Bridges are designed to carry a load of 100 pounds per square foot, or two 24-ton electric cars, coupled, or side by side on two tracks. The masonry supporting highway bridges will be of first-class rubble, laid solid in cement mortar.

Extensive facilities have been provided for the freight traffic, comprising three main yards, with numerous side tracks, all to be provided with the best and latest improvements as to frogs, switches and signals.

These yards have a combined area of about sixty acres, with a capacity of 2,000 cars.

While such yards and capacity will not be needed for a long time, it was thought best to secure the land now. This consists of large undeveloped areas, near the tracks or the existing yards, which, in the great probable development of Brockton, might be entirely unobtainable ten years later. These yards will be graded only at present to such an extent as to provide for the next ten years' business.

The main freight yard will be at Brockton, and will have an area of about forty acres.

The grade of the yard, when finished, will be 24 feet below the

grade of the tracks as raised, and, to get into the yard from the main tracks, a switchback will be used. This switchback will be double-tracked, and will be in part on an 8 degree curve and on a grade of $1\frac{1}{4}$ per cent., 1,700 feet long, terminating at the switch, from which the tracks run back into the yard. From this switch the main tracks continue about 800 feet eastward, as switching tracks, or tail tracks, on an ascending grade of 0.5 per cent. These tracks will give room for handling a train of 20 cars.

The tracks running back from the switch above mentioned, will have a grade of 0.6 per cent. covering a descent of 4 feet into the main yard, and to the freight houses. This yard could be operated by gravity were there any assurance as to the conditions of the brakes on the cars. Cars would run down the 1.2 per cent. grade for 1,700 feet, then strike an ascending grade of 0.5 per cent., 1,100 feet long, on which the momentum of the car could be stopped. After being stopped the car would run back down the 0.4 per cent. grade to the switch in the main freight tracks, thence back into the yard on a down grade of 0.6 per cent. on to any one of the tracks there, or to the freight house.

Special effort will be made to drain the main yard, and it is believed that this can be done by sloping the yard transversely, or north and south, on a grade of about 0.5 per cent. to the center, there collecting the water into catch-basins, which will empty into a [city] drain running through the yard, the drain being low enough to provide sufficient fall.

All switching will be done on the high-grade tracks, so that freight *trains* will not enter the yard at all, the work of shifting the cars up and down the grade into the yard being done by a switching engine.

New freight houses, 25 feet in width and 500 to 600 feet in length, will be built in this yard, probably one for shipping and one for receiving freight. A coal shed 80 feet wide, for a double track, and some 500 feet in length, with a capacity of 25,000 tons, will be built on the west end of the yard, adjoining the main line.

Entrances will be made to the yard on three sides, giving excellent facilities for shippers to get to and from the freight houses. One of these entrances will be through an arch of 30 feet span and 16 feet clear head room, under 9 tracks, 4 main and 5 side tracks.

At Montello and Campello, yards of about ten acres in each, will be graded, and onto these yards the present freight houses will be moved.

Through each of these three freight yards is a water-course—the main drainage of that section of the country. At Montello is an 8-foot arch, with 3-foot walls, 700 feet long; at Brockton, a 16-foot arch, with 6-foot walls, 140 feet long, and at Campello, a double 16-foot arch with 5-foot walls, 160 feet long.

The arches are, in all cases, of brick, the side walls of rubble masonry, and the invert and foundations for walls, of concrete. In two cases the foundations for these arches are known to be good, but at Campello, it may be in quicksand, though the depth of the excavation is not over 6 feet below the level of the ground, so that no great difficulty is anticipated.

The grade of the Brockton freight yard culvert is 17 feet below the level of the yard, but, as the whole channel of the stream is changed there, only the seepage of the ground and river water will be troublesome. This culvert is 5 feet deeper than the adjacent channels, being put down to the proposed grade, as established by the city of Brockton. A branch of the main water-course crosses the present tracks of the railroad just south of Crescent Street, through an opening of about 24 feet, spanned now by girders. This channel will be lowered about two feet, and an arch of 22 feet span, with 5-foot walls, will be built to convey the stream.

This arch and the adjoining retaining walls, made the heaviest piece of masonry in the whole scheme, the walls being 30 feet from foundation to grade, and 200 feet long. As the limits of the right of way here are about 70 feet, and on both sides are new walls 20 feet high, which must be rebuilt, and as the railroad traffic must be maintained, this piece of construction will be about the most difficult to handle of any.

The proposed method of construction is to build two temporary tracks on the limit of the land acquired, on the east side of the tracks at the present grade, for operating the road; the freight traffic, switching, etc., having been provided for in the new freight yard now well along in its construction. This will keep the freight traffic clear of the operating tracks. As arches are to be built at all the main crossings, the centering for masonry will block the street, but it is proposed to build one arch, or enough of it to get two tracks across, at a time and leave the adjoining streets open. As there are five crossings within 1800 feet, the inconvenience to the public (teaming and electric cars only, for provision for foot travel will probably be made under centers and timbering) will not be great; but as the streets are to be lowered from 2 to 7 feet within this distance, and as the finished clearances are to be from 13 to 16 feet, the head room will be reduced to about 10 feet until the traffic is turned onto the two high tracks. While these high tracks, and the walls and arches, are being built, the west and main passenger station, with its grounds and approaches, will be constructed, so that when the traffic is turned onto the high grade the new station will be in readiness. In most cases we have land enough to build two tracks, allowing for full slopes, but where we are limited we shall either put the high tracks upon a trestle, or crib up the slope from the high grade to clear the low

tracks. Where the tracks are to be lowered, the cuts (all sand) will be widened out on the west side to the true slope at the present grade, and two tracks will be thrown over as far as possible in the new cut. Then, with teams or by train, the east side of the cut can be taken out to the low grade and wide enough for two tracks, which will be laid there and the traffic turned thereon, after which the rest of the cut will be taken out.

Throughout this lowering, with the exception of some 150 feet, we have acquired land enough for the full slope. The material, some 150,000 yards, excavated in this cut, will be hauled into the adjoining streets, which are to be raised or replaced with new ones, or into the embankments or freight yards.

Many changes are to be made in the grades of the streets, every one of those crossed being changed, to get over or under the railroad, and these changes of grades in many cases will involve other streets adjacent to the grade crossing abolished. These changes are in most cases such as to necessitate the reconstruction of the water and gas pipes and sewers, and in many cases the construction of new drains for the disposal of water, which will be changed in its flow by the changes of grade.

All these streets are to be either paved with granite blocks, or to have a macadam paving 8 inches thick, with edge stones, crossing, etc. The decree of the Commissioners requiring this work to be done, "for the security and convenience of the public," was signed on March 8, 1894, and it is expected that the work, already begun, will be finished within three years. The estimated cost is \$1,500,000, of which amount the railroad pays 65 per cent., the State 25 per cent., and the city of Brockton 10 per cent. The Commissioners, appointed by the Court, under whose direction the plans for this work have been made, were Hon. B. W. Harris, of Bridgewater; Charles B. Barnes, of Boston, and H. C. Southworth, C. E., of Stoughton. The engineering has been done by F. H. Snow, City Engineer, for the city of Brockton. Plans of stations have been prepared in the office of Bradford L. Gilbert, of New York; and the Old Colony work has been done by the writer.

ABOLITION OF GRADE CROSSINGS ON THE PROVIDENCE DIVISION OF THE OLD COLONY RAILROAD IN BOSTON.

BY JAMES W. ROLLINS, JR., ENGINEER FOR THE RAILROAD COMPANY.

[Read December 19, 1894.]

THE abolition of the grade crossings on the main line of the Providence Division, in the city of Boston, will require the elevation of the tracks of the railroad ; beginning at Massachusetts Avenue, thence rising on a 0.6 per cent. grade to an elevation of 18 feet above existing tracks at Roxbury Station ; this elevation is maintained, from 18 to 20 feet, to Washington Street, Forest Hills, where the grade begins to descend to meet the old grade some 3,000 feet south—the new grade of the West Roxbury Branch runs out at the Bussey farm arch some 2,000 feet from the junction at Forest Hills.

This involves a change of $4\frac{1}{2}$ miles of road, over which on three tracks, is now handled a daily train service of 186 regular trains, besides numerous "extras." Generally this raised grade will clear the highways, although Ruggles Street, being only 3,700 feet from the beginning of the change, will have to be lowered $4\frac{1}{2}$ feet. The lowering of this street will necessitate the changing of the Stony Brook conduit which crosses the railroad in Ruggles Street in two 8-foot arches, and has various connections, tide-gates, etc., so close as to be involved in the lowering of the grade of the street.

It is proposed to substitute five 48-inch pipes for these two arches, and, in that manner, gain the necessary head room.

Tremont Street, at the Roxbury crossing, will be lowered two feet and spanned with a steel arch of a span of 80 feet.

Somewhat similar arches are proposed at Morton and Walk Hill Streets, at Forest Hills, and the rest of the bridges are plate-girder deck bridges, with solid iron floors covered with concrete and ballast, and are to be water-tight. Twelve grade crossings are abolished. Centre Street at Hogg's bridge, now an overhead crossing, will be lowered 18 feet, and the railroad will be carried over it. Two new streets are provided for in the elevation—Mozart Street, just north of Boylston Station, and William Street, between Green and Keyes Streets, at Forest Hills.

In addition to these, the Park Commission of the city of Boston will build a bridge under the tracks, as raised, just north of Morton Street at Forest Hills.

This bridge, as shown by preliminary sketches, will consist of three

arches—one 44 feet, and two 22 feet, in clear span at right angles to the street line, finished with a heavy and ornamental coping and railing, which makes a very massive and handsome structure.

Subways will be built between stations, thus making a total of 15 street crossings, 5 subways, and the park-way arches, as above described, to be built under the change.

The plans, as signed by the Commissioners, show retaining walls to be built, from Prentiss Street to Old Heath Street, on both sides of the track; and from Boylston Street to Green Street, on the west side; and from Green Street to Keyes Street, on the east side, with short lengths in various other places to protect station-grounds and private property.

For the rest of the distance, land has been taken for slopes.

These retaining walls will require more than 100,000 cubic yards of masonry, which, together with the various other constructions, will make an aggregate of at least 125,000 cubic yards. The filling required will exceed one million yards.

The plans, as originally signed and filed early in 1893, maintained the railroad in its elevated grade, clear of Stony Brook which runs close to the tracks for 2,700 feet near Boylston Station, and 1,800 feet south of Forest Hills on the West Roxbury branch.

This construction required heavy retaining walls, and left the brook in its old location and grade, to be rebuilt later by the city of Boston when the change of that troublesome stream should be made to the low grade, as reported upon by the Commission in 1889.

By agreement with the parties in interest, a change was made in the plans where Stony Brook was involved, whereby the railroad company took extensive areas of land—enough to admit of moving the brook over far enough from the railroad to permit its being reconstructed on the new low grade, which is 13 feet lower than the present grade, and, also, to clear the slope of the railroad. The section to be rebuilt, near Boylston Station, some 2,700 feet long, is a 15½ x 17 foot brick conduit, with concrete invert lined with brick, and with rubble masonry backing.

Borings showed all kinds of material to be met with in the excavation. Hard-pan at the north end (which the excavation has developed into a rotten rock), then a section of 700 or 800 feet of quicksand, the cutting being about 22 feet deep, then a like distance of hard-pan or rock—probably the latter, in a cutting from 25 to 37 feet deep. The new channel is from 7 to 20 feet from the old channel, which is open, with side walls of Roxbury pudding-stone, laid up dry.

The net cost of this Stony Brook construction is materially lessened by the fact that the surplus material is put into the railroad

embankment, and so, practically, costs nothing, embankment only being estimated for the railroad work. It is to be hoped that when this section of the improved channel is completed, Stony Brook will be in its grave, for the struggles that the old town of West Roxbury, and later the city of Boston, have had with it have been many and costly, and must often have led the authorities who had to deal with it, and the taxpayers who had to pay for that "deal," to wish that the recommendation of some Boston aldermen "to discontinue the —— brook," might long ago have been adopted.

At Forest Hills, a section some 270 feet in length, a double 8-foot conduit will be built, and from there to the end of the change an open channel outside the slope of the railroad in its high grade.

The station arrangement is, in all cases, for a double station, connected by subways. Waiting-rooms are, with the exception of Roxbury, on the grade of the elevated tracks, and have stairways to the street level; as have also the platforms which are generally 15 feet wide at the station, and for about 200 feet each side; beyond this to a total length of 600 or 700 feet they are 7 feet in width.

Express trains are to run on the two inside tracks, and these tracks will be fenced off so that there will be no crossing of track at grade, and passengers alighting from local trains will be in no danger from the express trains which can then run regardless of locals and of their passengers.

All freight tracks now in use will be abandoned on the elevated grade, and, in substitution for them, quite an extensive yard is laid out on Lamartine Street from Centre Street almost to Boylston Station. This yard can hold 100 cars, and has tracks outside the main line on which to do all shifting.

The estimated cost of this work is about \$3,500,000; of which the Old Colony Railroad pays 55 per cent. or \$1,925,000, the city of Boston \$472,500, and the State \$1,102,500.

This work being done under a special Act of the Legislature, the State's proportion amounting to \$1,102,500 does not come out of the five million which, under the Act of 1890, is the limit of the State's share.

DISCUSSION.

MR. CHARLES A. ALLEN.—I have been very much interested in Mr. Rollins' description of the work to be done on the Providence Division of the N. Y., N. H. and H. R. R., and at Brockton, because, as far as I know, they are the first two comprehensive schemes for carrying out the abolition of grade crossings where more than one or two crossings are directly concerned.

When the Act of 1890 was first passed by the Legislature, the tendency, especially on the part of the engineers representing the cities and towns, and on the part of the town authorities, was, to look upon the different streets in cities and towns as being independent of each other, and as furnishing problems which could be solved independently of one another. This was very soon found to be a mistake, and, as a consequence, very much work that would otherwise have been done in the abolition of grade crossings has been delayed, and I think for very good reasons indeed.

I have been asked to say something in relation to matters we have had under consideration at Northampton, and, as it is in a direct line with the sentiment expressed, that crossings in the cities and towns are often more or less intimately connected, I will say a few words on that subject.

Very soon after the Act of 1890 was passed, for the gradual abolition of grade crossings throughout the State, a petition was filed with the Superior Court for the appointment of a commission to consider the matter of the abolition of the grade crossings at Northampton. The city authorities had little idea of what was required.

A commission of three gentlemen was appointed, one of whom was Mr. E. K. Turner, formerly the Chief Engineer of the Fitchburg Railroad.

The plan presented by the Connecticut River Railroad, then an independent line, was to carry the streets over the railroad without much change of grade of the tracks. This plan was not popular in Northampton, and the city authorities very soon saw that they would need some one to assist them in the matter. They employed the late Augustus W. Locke, then a very able member of this Society, and also a very able and intelligent engineer; and he devised a scheme for elevating the railroad tracks and depressing the streets. This plan did not provide for changes in the location of freight yards, but was necessarily a very hastily devised scheme, but it was presented to the Commissioners. They had a number of hearings, and at this time I was called into the case.

After a somewhat hasty study of the question, as the time was limited, it seemed to me that the plan proposed by Mr. Locke was the best one. This plan was presented to the Commissioners, but they adopted the plan presented by the Connecticut River Railroad. The decree was reported to the Court, but was contested by the city. The Court, however, confirmed the decree.

The city then went to the Legislature for relief, and had a bill passed which I think is unique in the legislation of this State, or in any other State for that matter. It provided that no street grades should be

changed except with the consent of the City Council. It virtually set aside a decree of the Superior Court, and it was considered by many eminent lawyers to be unconstitutional. It was taken to the Supreme Court and very ably argued by both sides. The Supreme Court decided that it was constitutional, and that the Act must stand. The parties interested were thus left in a position where the city could not move because it could not change the location of the tracks, and the railroad could not move because they could not change the grade of the streets.

It was very soon found that some arrangement must be made to bring about an agreement in the matter, so a meeting at Springfield was arranged with the railroad officials, and it was agreed that if Mr. Curtis, Chief Engineer of the N. Y., N. H. and H. R. R., Mr. Bissell, Chief Engineer of the Boston and Maine Railroad, and Mr. Locke would agree upon a plan it would probably be adopted. In going from one of the meetings held following this decision, Mr. Locke caught a very severe cold, and it was the last time he appeared, for his illness terminated fatally. Having been more or less mixed up in the matter, I was called in to take his place.

Very soon after this a meeting of the engineers was held and work was begun in earnest upon the plans, with the result that a scheme was developed which provided for elevating the tracks and for the construction of a new Union Station, a new engine house and new freight yards, at the northern end of the city.

The original decree was referred back to the Commission within a week, and I presume that very soon the question will be settled so far as Northampton is concerned, and, I think, in a very admirable way.

These are the difficulties we labored under in the settlement of this question, and it calls out the point I wished to call attention to, as suggested to me by Mr. Rollins' paper, although it seems almost absurd to suggest this at a meeting of engineers. It is this: that plans for the abolition of grade crossings in cities and towns, like those for the construction of waterworks or sewerage systems, should always be thoroughly considered before a decision is arrived at.

I have had the honor to be connected with a number of these questions throughout the State. Among them I call to mind at this time the matter of the abolition of the grade crossings in the city of Newton.

The Boston and Albany Railroad officials devised a plan for the elevation of their tracks on their present location, and, after a very careful study of the matter, we reported in favor of the same plan. It seemed to be the best thing to be done under the circumstances, but there is this difference between us: I thoroughly believe, and I have advocated, that we should have much better work in the way of bridge construction. I do not mean that the bridges should be built in a more

substantial manner, but that more attention should be given to architectural and artistic effects in constructing bridges, more particularly in the populous parts of the country, and especially in cities as large as Newton and Worcester. I know that a great many engineers do not agree with me in this matter. I think, however, the reason is, that the railroads have a very large portion of the expense to pay, and perhaps there is a great deal to be said in favor of their position. The cities and towns pay but 10 per cent. of the expense of construction, and, if anything more than strength is required, I think they should pay a larger portion of the additional expense. I do not think the railroads should be called upon to pay anything more than is required to construct a bridge in a thorough manner. I am very glad to see in these two cases, of which the details have been presented by Mr. Rollins, that a very decided step has been taken in the right direction. As I understand it, the bridges on the Providence Division are to be steel arches, with some masonry arches, and at Brockton masonry arches are to be used almost entirely. I believe this is right, and where it can be done it should be done.

I have examined a great many bridges of all descriptions, both in this country and abroad, and I am obliged to say that for architectural effect our bridges are not to be compared with those spanning highways in France, Germany and England. I understand that the latter have been built under circumstances different from those we have here, but I think our cities and towns ought to pay, in addition to the amount required to build a strong, substantial structure, a sum sufficient to make it at least presentable.

In his paper Mr. Rollins has referred to the construction of electric roads crossing railroads at grade. It seems to me that this is positively the most dangerous thing that can be done. I do not think it should be permitted under any circumstances, except as a temporary measure.

We have had all over the State very many escapes from bad accidents due to this method of crossing. In Worcester, a short time ago, a car loaded with passengers stopped on the railroad track while crossing, as the electric current gave out. An express train was approaching rapidly. This train was stopped barely ten yards from the car. Most of the people on the car were too terrified to move, and a terrible accident would have happened had the train struck that car, even at a low rate of speed. Accidents are liable to happen at almost any time in a similar manner. Look at the accident at Southbridge. I have heard it stated that this crossing ought to be abolished, but after the town found that it would have to stand 10 per cent. of the cost of its abolition, nothing further was heard of it, and it was thought that perhaps it was not a very bad crossing after all, because no one had ever been injured there. This argument is very often used.

It is, of course, a very serious question where the money is coming from to abolish all the grade crossings in the State, and it is not to be supposed that the railroad corporations will rush into the matter any faster than they feel they are obliged to. It means to them, to the State, and to the cities and towns, the expenditure of an immense amount of money. We are moving in the right direction, however, and the grade crossing has got to go. The only thing to do is to take hold of these questions as they come up, and then settle them in the very admirable way in which the questions before us have been settled by the engineers in charge of the Boston and the Brockton matters.

MR. JOHN W. ELLIS.—The elimination of grade crossings is a question of very grave interest and importance to every engineer, and one that calls for engineering skill, experience and careful study. In the matter of electric railroads, no other element is, perhaps, of more importance. A railroad, with steam for motive power, crosses a highway, and is condemned as a nuisance, but the street railway, with electricity as a motive power, runs parallel to the railroad on the highway. I call such an arrangement a street railway grade crossing throughout its whole length.

It has been my good fortune to act as engineer in several instances for the elimination of grade crossings in all its phases, as consulting engineer for railroads, cities and towns, and it seems to me that, on the average, the railroads are compelled to bear the brunt of the expense of the necessary changes. I am stating things generally, not specifically. The railroads are very likely to look to the necessary expense of the improvement rather than to the public convenience; the public looks to the appearance of the work, rather than to its practicability taken as a whole, while outside parties sometimes present, in their own interests, plans based more or less on speculation. In order to make a fair and impartial decision, we must take all these things into consideration and present them to the engineer and to the commissioners; and a proper solution of the problem requires the most careful examination of the details presented. You must consider the matter thoroughly and deliberately before you can be ready to grasp the question and settle the problem.

In Providence, a satisfactory agreement between the city and the N. Y., N. H. & H. R. R. was made in regard to the grade crossings north of the terminals. I think it was proposed, when the Legislature came in session, to pass a grade crossing law, but it seems now to be the general opinion that it is good policy to learn wisdom from your State. A reasonable time should be spent by the parties in interest, to see if they cannot agree, and they should not be allowed a commission until they have formulated a plan that they would wish to present to the commissioners when they are appointed.

Mr. Rollins' statement of the proposed changes of grade on the Providence Division has greatly interested me. If, on this question of the elevation of the tracks, and in the capacity of Inspector on the Old Colony Railroad, the Directors had asked me what effect I thought it would have on the property of the Providence Division, I would have replied that I did not think that came within the scope of the engineer. But it is quite a serious question whether the suburban travel would or would not take the electric cars in preference to it. Then, too, consideration should be given to the decrease of value which is liable to occur to the lessors in this case, who are held responsible by the stockholders to see that the value of the property does not depreciate.

MR. F. HERBERT SNOW.—I have listened attentively to all that has been said, but I have listened with the consciousness that for me, as a city engineer, it is impossible to look at the subject of the abolition of grade crossings from the standpoint of the railroad engineer. From the moment a scheme is started until everything is settled these engineers work upon widely different premises. Each will labor to save the money of his employer, and just so far as the city's interests and those of the railroad are at variance, just so far will their respective engineers be divided in their opinions.

Mr. Rollins has given us some substantial reasons why the head room of under-passes should be kept down to the minimum, but should these reasons be controlling ones?

I admit that in a discussion of this question the city engineer labors under a disadvantage. The arguments of the railroad engineer will be presented, with facts and figures hard to controvert, and they will, I am forced to believe, be likely to prevail; nevertheless, I submit that the question of head room ought not always to be settled upon the basis of the greatest economy to the railroad company. Why should it follow, because a project to abolish the grade crossings of a community must necessarily involve the expenditure of a large sum of money, that economy must be practiced chiefly at the highways.

It seems to me an erroneous idea that the only object to be sought and attained in the abolition of grade crossings is their riddance. There is a greater object, and it is found in the broad interpretation of the term public improvement. I argue that the abolition of grade crossings is a public improvement in the sense that the State recognizes it to be such, and (since such public works exert a positive influence upon the development of the varied interests of a city) if the diversified interests, present or prospective, of any community are to be given, as they should be, an opportunity for full and unrestricted growth, the abolition of the grade crossings should be so conducted as to provide, as far as possible, for that growth. Hence the desirability of liberal head room for under-passes.

This question can be definitely settled by the Legislature, and, since the clearance of bridges where a highway passes over the railroad is regulated by statute, it may be well to regulate in the same way the clearance where a railroad is to pass over a highway, fixing a minimum height for all cases.

In all that has been said in relation to stone arch bridges I can most heartily concur; and, furthermore, I would like to make a plea for the principles of beauty in engineering architecture.

It is to be regretted that those in authority have sacrificed these principles to economy in those Brockton stone arches, where there was a favorable opportunity and real need for the application of architectural symmetry and ornamentation.

I believe that sentiment should not be left wholly out of consideration in public works of this kind. If it is true, as many claim, that the influence of architectural beauty, even in a stone arch bridge spanning a highway, acts upon all classes as an incentive to improvement; if it increases the attractiveness of the city, making it more desirable to reside in by thus adding to its respectability, then I am supported in my belief that towns and cities and, above all, the State should encourage and promote the principles of beauty in engineering architecture.

I am not unmindful of the fact that a railroad company is a money-making corporation, and hence its opposition to any plan or principle involving the expenditure of money not required for practical purposes must be expected. But this natural and proper opposition ought not to deter the town or city engineer from his duty. With him the question is not, what proportion of the entire cost of abolishing the grade crossings the town or city is to pay. His duty is the same, whether the town or city pays the whole cost or none of it.

It is pertinent to this line of thought to touch upon the question of the extent to which the people of any particular place can legally be interested in the plans for the abolition of its grade crossings. As the subject is now understood, the Superior Court decrees what shall be done; a commission is appointed to give hearings as to the necessity of the abolishment as asked for in the petition of the selectmen, the mayor or the president of the railroad company. At the hearing or hearings the public has an opportunity to be heard. If I am correct, as soon as the commission decides that public necessity does require an abolishment of the crossings, it proceeds to determine the manner and limits in which the work shall be done, and this it has a right to do without consulting the public. This being the fact, there is no opportunity for individual remonstrance to the plans. This is a good thing in some respects and a very bad thing in other respects. Even the right of the mayor to remonstrate effectually is debatable, so that it becomes a vexed question

for the city engineer to decide to what extent he is connected with the proceeding when he is instructed by the mayor to look out for the engineering interests of the city. Of course, the railroad officials will not fail to keep constantly before him the fact that the city pays but 10 per cent. of the entire cost.

The subject of land and grade damage has been an important one at Brockton. I was called upon to prepare plans and estimates of the cost of abolishing the grade crossings of a place where the development of adjoining property had been governed and controlled largely by its relation to the elevation and location of the railroad and by the privileges thus afforded, and where the rents of buildings and the values of land have come to depend upon the custom of the public to take particular streets or avenues in passing to and from passenger stations, upon grade crossings, and upon other facts which entered largely into the problem. In summing up the items of cost, I found the item of land and grade damage to be a large one.

This will be more or less true in other cities. But the engineer is most concerned, not in the extent of the item, but in its correctness, and I do not hesitate to say that no matter how much care has been exercised in studying details and estimating damages to every estate affected, or whether or not the engineer has anything to do with the final settlement of the claims, that one item will cause him more trouble than all others put together.

If the engineer is appointed to settle claims, he will be impressed with the manifold difficulties of the work before he has fairly made a beginning, and if higher authorities decide that the settlement of claims is not necessarily an engineer's work, and if others are appointed to do it, without the consent and knowledge of the engineer, his estimates are likely to be largely exceeded, and his judgment and competency brought into question.

After the preliminary plans of the Brockton scheme were agreed upon by all parties in interest, the railroad engineer and the city engineer took up separately the details of all those parts of the work in which their respective principals were most directly concerned, and upon the joint estimates submitted by the engineers the whole project was based. In making estimates of damages, great care was taken, and much time and special study were given to over 250 cases, in order to obtain estimates which should be fair, and yet large enough to allow for a liberal settlement.

We had good and sufficient reasons for every case and estimate, and we had confidently hoped, after having taken these infinite pains, that settlements could be effected in or out of Court upon the basis of our estimates. These estimates have not controlled in settlements,

and, while I do not find fault, nor in any way criticise the judgment of those who have been appointed and are zealously discharging the duties intrusted to them, I do criticise the railroad company for not allowing its engineer a voice in the matter of settlements.

The railroad company, which, by the decree of the Court in Brockton's case, is to do all the work—the city engineer directing that part of it in and under the highways—had to rely on the judgment of the engineers in the first place; and since the company decided to settle, out of Court, as many cases as possible, the least it could have done in fairness to the engineers was to allow them a chance to substantiate their estimates before settlements were made. Under these conditions you can readily conceive how an engineer could be more worried and perplexed and hindered than if the whole job of adjusting damage claims devolved upon him. I say, therefore, to the city engineer: Look out for the correctness of the item of land and grade damage, and do your best to secure a voice, either for the railroad engineer or for yourself, in the settlement of claims.

Right in this connection I might refer to those parties owning business properties adjacent to and depending upon the railroad and its facilities, who cannot recover damages, really serious in some cases, resulting from the elevation or depression of the railroad tracks. The railroad company claims the right to elevate or depress its road-bed without considering the consequent damages to abutting properties, but I ask this question: Since public interest requires the railroad company to alter the conditions under which thousands of dollars have been invested in developing and equipping private property, with facilities for doing business with the railroad, and since these alterations—called for by public necessity—cause serious damage to these private properties, would not a claim for compensation here be as valid as that for damages to estates abutting on a highway where changes in grade are made?

MR. GEORGE A. KIMBALL.—I have been much interested in Mr. Rollins' description of the proposed changes at Brockton and in Boston on the Providence Division of the New York, New Haven & Hartford Railroad. Both of these improvements were recommended in 1889 by the Grade Crossing Commission, of which the late Mr. Locke was chairman.

I wish to add my testimony to that of Mr. Allen in regard to the importance of considering these questions in a comprehensive manner, as has been done in these two cases. To mature plans of this magnitude requires careful and patient negotiation. The plans presented this evening are the result of nearly five years of study and negotiation between the parties interested. The results are a credit to the officials of the cities and of the railroad company.

Years ago engineers would hardly have dared to recommend such marked changes in the grade of the railroad as are proposed in the two improvements described. I think it was twenty years ago when the matter of raising the railroad tracks came up in Springfield. At that time the County Commissioners decided to separate the grades, and they sent in a decree demanding that the railroad companies raise their tracks, substantially as they have now done. This was opposed by the railroad companies and was finally sent to the Supreme Court. The Court decided that the County Commissioners could not compel the railroad companies to raise their tracks. The decree of the court is contained in the Massachusetts Report 116, page 78, and a portion of it reads as follows:—"The much greater weight and speed of the engines and cars moved by steam upon a railroad, than of the wagons and carriages traveling upon an ordinary highway, render it necessary that the railroad should be constructed nearly upon a level, and make it much more practicable, in accommodating the necessities of the one to those of the other, to vary the grade of the highway than that of the railroad."

The decision was made in the year 1874, and we find that a few years later the railroads voluntarily raised their tracks and built a beautiful stone arch bridge over Main Street.

In making these improvements I would be glad to see more substantial masonry arch bridges built instead of the common iron bridges which are usually erected. The stone arch can be made to please the eye, and, when once built, it is good for a great many years with little expense for repairs. The Pennsylvania Railroad Company's Chief Engineer writes me that iron bridges do not last more than ten or fifteen years under their traffic, no matter how heavy they are built. They constantly need painting, new floor, etc. They have masonry arch bridges forty years old, that have not required more than forty dollars for repairs in fifteen years.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

L'Esposizione ed i Congressi di Chicago, NEL 1893. By Cav. Ing. Celso Capacci. Florence. 1894.

Those who had the good fortune to meet Cav. Capacci during his visit to this country and to the World's Fair will note with interest the appearance of this report, in which he describes the impressions gained here.

A dozen pages are devoted to a description of New York City and its various points of interest, and half as many to a brief account of the three principal national engineering societies. As the exhibition itself is handled in thirty-three pages, and the International Congress in fourteen more, it will be readily understood that our author has not undertaken to give to his compatriots more than a superficial view of the great exhibition. Three pages are devoted to California, and a table of a few of the more common English measures, with their metrical equivalents, is given.

Diatoms in Surface Waters. SOME OBSERVATIONS ON THE GROWTH OF —. By George C. Whipple, S.B., Biologist in charge of Laboratory of the Boston Water Works, Biologist of the Water Works of Lynn. Reprint from the *Technology Quarterly*, October, 1894.

If an engineer in these late days is ever tempted to imagine that he knows it all, such works as these, showing how largely he is dependent upon specialists in other lines, ought to correct the error.

Mr. Whipple, after briefly referring to the very complete system of work at the Boston Laboratory, defines diatoms as minute plants forming a group of microscopic algæ, containing over one hundred genera, of which, however, not more than twenty are commonly found in our water supplies, and only six have thus far been found to be of practical importance.

Except that "Asterionella is the diatom which is most active in producing tastes and odors in the water," we do not find that our author states to what extent these growths are injurious to a water supply. He does, however, urge the importance of removing the top soil when preparing a reservoir for the storage of water, inasmuch as the neglect of this precaution encourages these diatom growths.

Mr. Whipple reaches the following conclusions:

(1) That the growth of diatoms in ponds is directly connected with the phenomenon of stagnation; that their development does not occur when the lower strata of water are quiescent, on account of greater density, but rather during those periods of the year when the water is in circulation from top to bottom.

(2) That diatoms flourish best in ponds having muddy bottoms.

(3) That in deep ponds there are two well-defined periods of growth—one in the spring and one in the fall; that in shallow ponds there is usually a spring growth but no regular fall growth, and that other growths may occur at irregular intervals as the wind happens to stir up the water.

(4) That the two most important conditions for the growth of diatoms are a sufficient supply of nitrates and a free circulation of air, and that both these conditions are found at those periods of the year when the water is in circulation.

(5) That while temperature has possibly a slight influence on the growth of diatoms, it is of so little importance that it does not affect their seasonal distribution.

(6) That the increase of diatoms takes place substantially in accordance with the law of geometrical progression, and that the cessation of their growth is caused by the diminution of their food supply.

The Mechanical Engineers' Pocket-Book.—A reference book of rules, tables, data and formulæ, for the use of engineers, mechanics and students. By William Kent, A.M., M.E. First thousand, first edition. New York: John Wiley & Sons, 1895. 1087 pages, 4x6½ inches, including index. Price, \$5.00.

To attempt anything like an adequate review of this admirable work would be idle; first, because it would occupy an entire number of the JOURNAL, and second, because no engineer, mechanical, civil, mining, electrical, hydraulic or marine, can afford to be without a copy, and hence an extended review is uncalled for.

Suffice it to say here that every page gives evidence of conscientious pains-taking on the part of the author, who, while he has freely (and most properly) availed himself of results published by others, has done so without falling into those scissors-and-paste methods which have made the average pocket-book the useless article it is.

The publishers seem to have vied with the author in making this book what it ought to be, and the result is a thoroughly presentable, readable and indispensable addition to the Engineers' Library.

Portland Cement. A monograph. By Charles D. Jameson, Professor of Engineering, State University of Iowa, Iowa City, Iowa, 1895. *The Transit*, Vol. III, No. 1, January 1895.

An entire number of *The Transit*, containing 192 pages, is devoted to this valuable treatise on Portland Cement. The author has already commended himself to public favor by a series of admirably written papers on Railroad Surveying, and the care and thoroughness bestowed upon their preparation has evidently not been withheld in the writing of the present paper.

The author covers the entire ground of his subject, embracing the natural materials entering into the composition of cement, their preparation, the history of the manufacture and use of cement, cement specifications and tests, the chemistry of the hardening of cements, and the use of cements in actual construction.

Typographically the work is well presented, and it is thoroughly and admirably illustrated. The illustrations include a number of fine photographic views showing the use of concrete on the Hennepin Canal and at the Leland Stanford, Jr., University.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.



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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

THE CHICAGO SANITARY DISTRICT CANAL.

IV. Description of the Work and Methods of Construction on the Summit Division.

By E. R. SHNABLE, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read, February 6, 1895.*]

INTRODUCTORY.

ALTHOUGH the force on each section is carefully taken twice a day, a discussion of the cost of the various methods employed on the Summit Division must necessarily be omitted at this time. This subject cannot be taken up, properly, until after the completion of the canal. I will, therefore, ask the Society's indulgence while describing briefly other matters of less interest.

LOCATION.

The Summit Division comprises sections "C," "D," "E," "F," "G" and "H." The first three being west of the Summit—Riverside Road—and the last three being east thereof. Section "F" occupies the lowest divide between the Mississippi Valley and the Basin of the Great Lakes. Before the river diversion levees were constructed, I have seen the spring freshets of the Des Plaines River and the melting snow and ice on this section flow westerly over the Summit Road and

* Manuscript received May 3, 1895.—*Secretary, Ass'n of Eng. Soc's.*

easterly into the Ogden Ditch, which empties into the Chicago River. The tangents of the main channel were located nearly parallel to the old Illinois and Michigan Canal, the 3-degree curve of this canal being replaced by a 30-minute curve of the new canal. This curve is 6,510 feet long and lies across the east half of Section "E," across Section "F," extending 100 feet into Section "G." The center of the curve was located from the point of intersection. The initial point of the location being at the Willow Springs Road the curve was turned from the P. T. It was measured over levees, private railroad tracks, a highway embankment, through ice loading platforms, willow brush and weeds, with water standing two feet deep in places, and checked on the center of curve and P. C. to one-tenth of a foot for distance and the width of a flag-pole for alignment.

CROSS-SECTION.

The cross-sections are from 31 to 40 feet deep, 202 feet wide at the bottom, with 2 to 1 slopes, 27½ feet above grade, above which point the slopes change to 1½ to 1. This channel, of 600,000 cubic feet per minute capacity, is being constructed from Willow Springs to the Summit Road, where it contracts to the half-channel and thus continues to Robey Street in Chicago. The half-channel is 110 feet wide at the bottom, with 2 to 1 slopes to the surface.

MATERIAL.

The material, excavated and to be excavated, is composed of loam, decomposed vegetable deposits, sand, gravel, clays, hardpan and solid rock. The quantities in each section are approximate, until such time as the surface of the solid rock is completely uncovered. The total quantities to be excavated in each section, based upon the incomplete data now at hand, are as follows:

Section.	Glacial Drift.	Solid Rock.
C	1,887,755 c. y.	
D	1,877,721 "	137,694 c. y.
E	1,813,659 "	78,765 "
F	1,093,653 "	16,724 "
G	1,364,075 "	
H	1,077,032 "	
Totals,	9,113,895 c. y.	233,180 c. y.

These quantities, with 429,850 cubic yards in the River Diversion and Levees and a few collateral items, make the cost of the Division

\$2,772,909. Up to January 1, 1895, \$1,015,952.99 have been estimated, and, excepting the 12½ percentage retained, have been vouchered in semi-monthly payments.

SECTION "C," WESTERN DREDGING AND IMPROVEMENT CO.

The lower half of this section occupies the former bed of the Des Plaines River. Consequently the Diversion channel was necessarily excavated first. This channel has a base of 200 feet, 1 to 1 slopes, and an average cutting of about 5 feet. This work was done during 1893, with two Barnhart steam shovels and inclines, supplemented with a large wheelscraper force.

At the same time a large wheelscraper force excavated the first 8 feet of the east and dry half of the main channel. During November, 1893, a steam-shovel and work-train plant was installed, consisting of 2 special Barnhart shovels, 4 locomotives and 26 flat cars with a side-plow and cable. This method of unloading flat cars with side plow was soon abandoned. Large dump-cars, after the plans of Mr. J. O. Wright, General Manager, were built in Joliet and also by the U. S. Car Company. They are 12 feet long, 11 feet 8 inches wide and 18 inches deep, inside measure, of $7\frac{7}{8}$ cubic yards capacity, struck measure. These cars are wider than usually built, and have the advantage of clearing themselves readily in being dumped. The overlying earth and soft clays having been removed by teams, the material left for the steam shovels is found to vary in short distances. The formation is of the nature of hardpan and boulder hummocks or waves with pockets or hollows of sand and sandy clay. The two shovels, progressing longitudinally, may have 50 feet of free digging, while the next 100 feet of progress may require drilling and blasting.

The output per working day consequently varies. For July the average output per working day per shovel was 762 cubic yards; in August, 533 cubic yards; in September, 820 cubic yards; in October, 493; in November, 503, and in December, 538.

The daily force is distributed as follows:

OUTPUT AND DISPOSITION OF MATERIAL.

2 Foremen,	2 Shovel Enginemen,
2 Cranesmen,	2 Firemen,
8 Pitmen,	4 Locomotive Enginemen,
4 Trainmen,	18 to 26 Dumpmen.
3 to 12 Ditchers,	

REPAIRS OF PLANT.

1 Foreman,	12 Track laborers,
1 Machinist,	1 Blacksmith,
1 Blacksmith Helper,	2 Car Repairers.

DRILLING AND BLASTING.

3 Laborers.

PIT PUMPING.

2 Pumpmen.

FEED WATER SUPPLY.

1 Pumpman.

GENERAL EXPENSES.

1 Superintendent,

1 Watchman,

1 Timekeeper,

1 Electrician,

1 Swing Team.

Night work was abandoned on December 8th, on account of the cold weather. The plant consists of 2 steam-shovels, 4 locomotives, 32 dump-cars, 3 centrifugal pumps, 1 dynamo and $2\frac{1}{2}$ miles of standard gauge track. The first view, Fig. 1, is taken at about the middle of the section looking east.

SECTION "D."—E. D. SMITH & CO., CONTRACTORS.

The material in this section is similar to that of Section "C." The Des Plaines River, not interfering with the main channel and spoil bank as located, was not diverted. In April, 1893, the contractors began work by first putting up a temporary levee with a wheelbarrow force. Upon this embankment a standard gauge-track was laid, connecting their work with the Chicago and Calumet Terminal Railway. The next view, Fig. 2, is a map of this section showing the plan adopted by the contractors, and the gradual shifting of the tracks as the work progressed. It may be called a double "Y" stub-end method. The shovels were started at the center of the section, one headed east and the other west. When the work was started the tracks lay as shown and marked "AA." After each cut, as shown by the specimen cross-section on the left of the map (which is one of the monthly progress record), the pit-tracks are shifted, the incline-track correspondingly lengthened until they now occupy the position marked "BB." The unloading tracks were located as shown at "AA," and have gradually been moved to the position marked "BB," as the spoil-bank increased in width. 14° or 16° curves were adopted. The map also shows the various camp, store and shop-buildings in use. Two Worthington duplex pumps are located in the pit near the middle of the section. One is in constant service, while the other is held in reserve for emergencies, such as a heavy rainfall, or while the other pump is being shifted or repaired.

The waste-water is discharged into the Illinois and Michigan Canal through a ditch and box culvert. During the past year progress was materially aided by a large New Era grader and wheelscraper force; 352,430 cubic yards being removed by this method, "C."



FIG. 1.

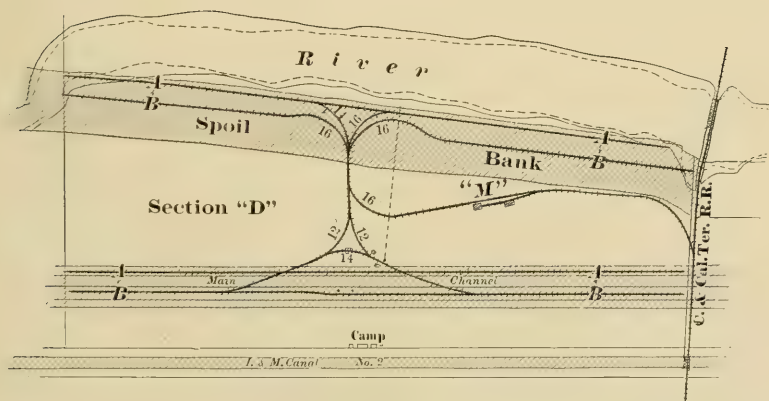
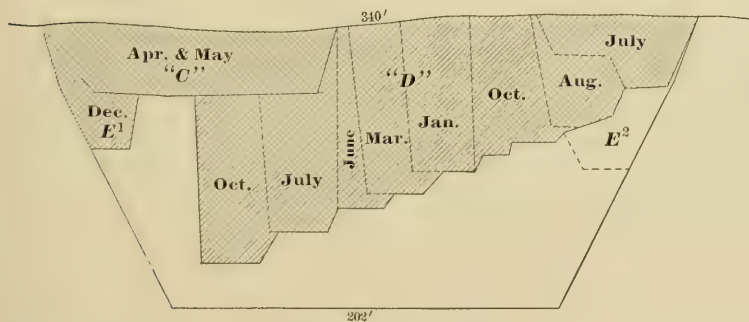


FIG. 2.



SPECIMEN CROSS-SECTION.

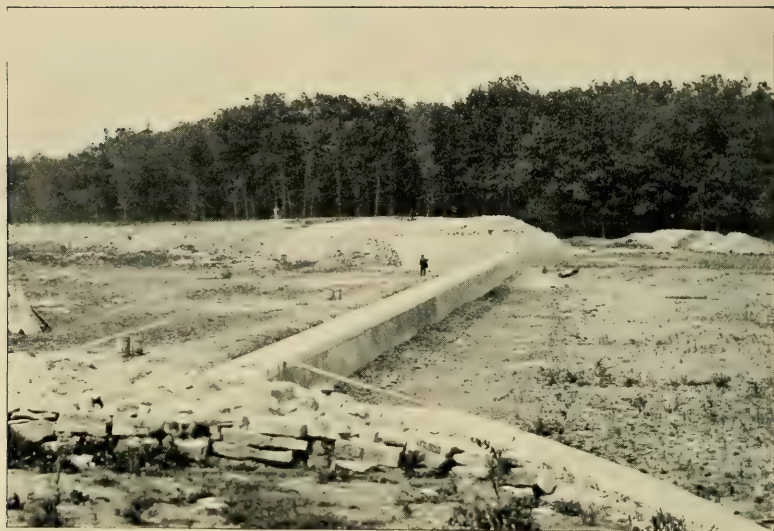


FIG. 3.

For Fig. 4, see folded insert sheet.



FIG. 5.

To insure the early completion of this section, a third steam-shovel was purchased. By referring to the specimen cross-section it will be seen that a large quantity of material will be left lying on the left-hand slope, "E," which the lower shovels cannot reach. The third shovel is now working down this slope, the material being loaded into 3 horse wagons. When this work is completed the shovel will be transferred to the right slope, "E₂," and will work down this slope in a similar manner. When the pit-shovels reach the foot of the left slope, at grade "D," they will begin excavating towards the right, on the plane of this grade. The method of working this section has been well planned, and is being managed with commendable executive ability. The entire plant was new when installed, and no changes of plan nor plant have been made since the work began. The plant consists of 1 "A" frame and 2 special Bucyrus steam-shovels, 4 Baldwin saddle-tank locomotives, 3½ miles of standard gauge track, and 40 Corey dump-cars. These cars are 9 feet 6 inches long, 8 feet wide and 2 feet deep, holding $5\frac{6}{10}$ cubic yards, struck measure. The daily average output per shovel has varied from 800 to 1,200 cubic yards per working day. Up to February 1st, 1,147,-731 cubic yards have been removed.

SECTION "E."—STREETER AND KENEFICK, CONTRACTORS.

The material in the west half of this section is similar to that of sections "C" and "D," lacking, however, its sandy and friable character. In the east half we find loam, clay, a homogeneous or cemented hardpan, cheesy clay, bull liver, boulders, and solid limestone, in the order named. The hardpan or boulder clay is too hard to excavate without the use of powder. Drilling is costly, as the imbedded gravel and small boulders bind the drill bar. This hardpan does not soften in the least under water, when first taken out of the pit. After a piece has been exposed to the air until dry it dissolves rapidly upon immersion. Bull liver, so called by well diggers, is a mixture of very fine sand, pulverized limestone, and water. It is water-bearing, but not porous, as hard to dig as clay when in place, and when stirred up as sticky as molasses and more treacherous than quicksand. As yet it has not been uncovered by the contractors, but was encountered in sinking test pits. Approximately there are 336,900 cubic yards of this material on this section.

During the season of 1893 the contractors removed the upper 3 to 8 feet (about 469,000 cubic yards) with a large wheelscraper force. The section was divided into five parts and the work was done by five outfits.

One of my assistants, Mr. J. H. Brace, tabulated the following information, showing a comparison, due to the nature of the material and management.

STATIONS.		Average Fill.	Average Cut.	Total Lift.	Average Haul.	Total Excavation.	Method of Excavation.
From	To						
460	470	<i>Feet.</i> 12.0	<i>Feet.</i> 8.0	<i>Feet.</i> 20.0	<i>Feet.</i> 400	<i>Cubic Yards.</i> 94,879	Wheeler scrapers.
470	480	12.0	8.3	20.3	400	98,515	"
480	490	11.0	7.0	18.0	400	85,761	"
490	500	7.0	3.4	10.4	400	33,185	"
500	507	7.0	4.3	11.3	400	29,678	"

STATIONS.		Daily Averages, Cu. Yds. Excavated.		Ratio of Teams.		REMARKS.
From	To	Per Team.	Per Wheel-scraper.	Wheel-scraper to Plow Team.	Wheel-scraper to Snatch Team.	Nature of Material.
460	470	29.8	42.2	$5\frac{1}{3} - 1$	$4\frac{4}{10} - 1$	Very stiff blue and yellow clay, with a few large boulders.
470	480	27.1	39.3	$4\frac{9}{10} - 1$	$4\frac{4}{10} - 1$	
480	490	24.4	35.2	$4\frac{8}{10} - 1$	$4\frac{3}{10} - 1$	
490	500	35.0	50.1	$4\frac{9}{10} - 1$	$4\frac{4}{10} - 1$	Stiff, yellow clay, containing a great number of boulders of all sizes.
500	507	28.3	42.1	$4\frac{6}{10} - 1$	$3\frac{7}{10} - 1$	

During August, 1893, a steam-shovel plant was installed, consisting of two Bucyrus shovels, four small locomotives, and fifty small, narrow-gauge dump cars. After a month's work the contractors were compelled to use powder, as the shovels were unable to dig the hardpan in paying quantities. January 15, 1894, this work was shut down, the contractors petitioning for relief. August 29th a re-letting was ordered. On September 19th, Angus and Gindele were awarded the contract. These contractors have adopted the steam-shovel and work train method, with standard-gauge track on the loop plan.

SECTION "F."—RICKER, LEE & CO., CONTRACTORS.

This section was more or less under water until July 15, 1893. Before that time the team forces were employed on the River diversion channel and levees. To guard against the destruction of the levees by an unheard of flood, a concrete masonry spillway, costing \$20,518, was constructed in November and December. The top of the levee has an elevation of 25 feet above Chicago datum, while the top of the

DISTRICT CANAL.

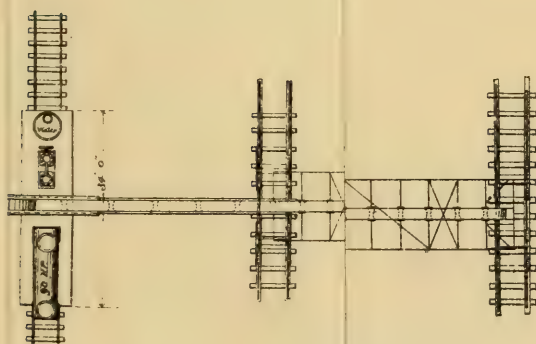
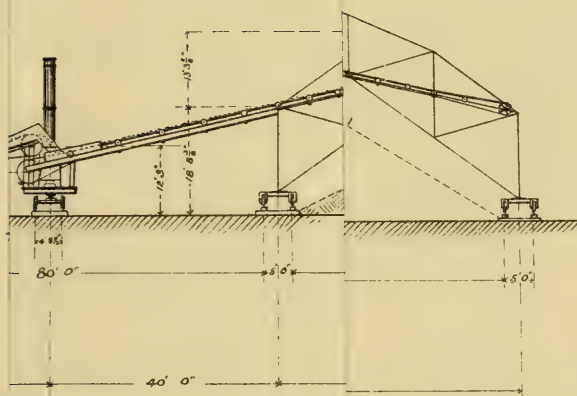
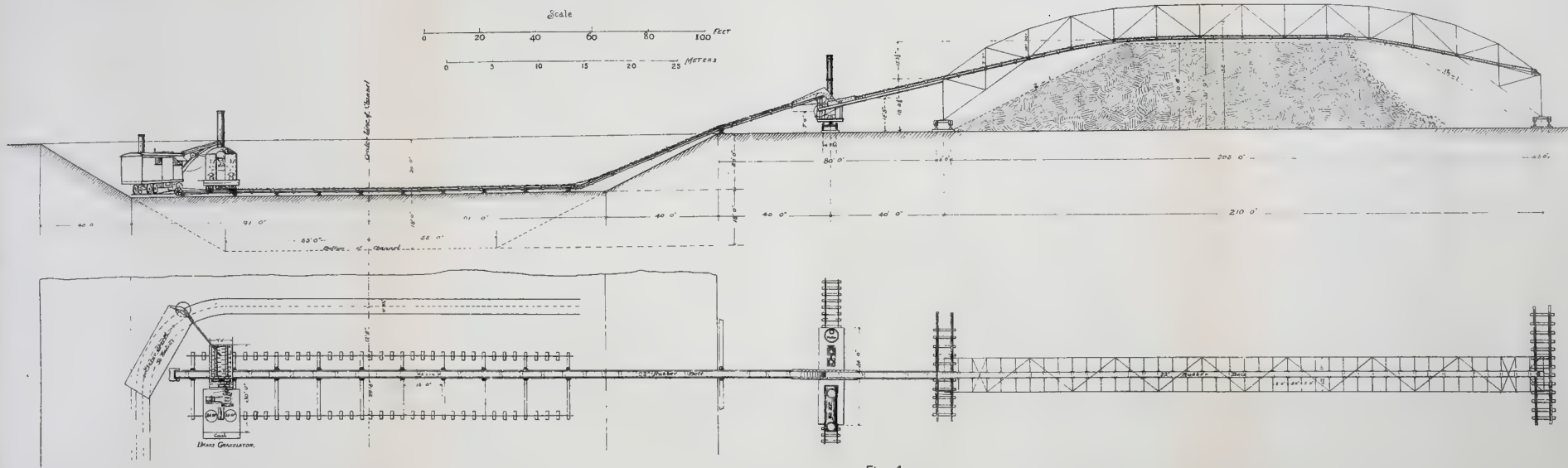


Fig. 4.

BELT CONVEYOR.

DESIGNED BY LINDON W. BATES.
CHICAGO, ILL.
JULY 31ST, 1894.



spillway is 16.25 feet above datum. This spillway is now the lowest divide between the Mississippi Valley and the Basin of the Great Lakes. The flood-waters of the Des Plaines River poured over this spillway last March for but a short period of 61 hours. After provisions have been made for carrying the combined waters of the Drainage Canal and Des Plaines River through Joliet, the height of the spillway will be raised sufficiently to prevent any of the flood-waters from reaching the Chicago River. The next view, Fig. 3, shows this spillway, looking north.

The material of this section consists of loam, soft clay (with beds of sand in which were found trunks and branches of trees, small shells and black walnuts), boulder clay or hardpan, cheesy clay, bull liver, boulders and solid lime stone, in the order named. Two steam-shovels and a large team force were employed at the same time. The section being in water-bearing strata, the shovels were worked on a lower plane, thus permitting the working of teams. The material was thus removed down to the boulder clay. The contractors then made another start, with steam shovels alone, employing a force of drillers and blasters.

To show the difference in material, I will add the force account and the corresponding output for a month's work in the upper clay and the same for a month's work in boulder clay.

IN CLAY.

The daily force is distributed as follows :

OUTPUT AND DISPOSITION OF MATERIAL.

2 Foremen,	4 Locomotive Firemen,
2 Shovel Enginemen,	5 Trainmen,
2 Cranesmen,	25 Dumpmen,
2 Firemen,	2 Ditchers,
12 Pitmen,	2 Waterboys.
4 Locomotive Enginemen,	

REPAIRS OF PLANT.

1 Foreman,	1 Car Repairer,
10 Trackmen,	1 Blacksmith,
1 Machinist,	1 Blacksmith Helper.

PIT PUMPING.

2 Pumpmen.

FEEDWATER SUPPLY.

1 Pumpman.

GENERAL EXPENSES.

1 Superintendent,	5 Watchmen,
1 Timekeeper.	

PLANT EMPLOYED.

2 Bucyrus Steam Shovels,	30 Thatcher Dump Carts,
3 Pumps.	

The daily average output per shovel for the month was 732 cubic yards.

IN HARDPAN OR BOULDER CLAY.

OUTPUT AND DISPOSITION OF MATERIAL.

2 Foremen,	3 Locomotive Firemen,
2 Shovel Enginemen,	2 Trainmen,
2 Cranesmen,	12 Dumpmen,
2 Firemen,	2 Ditchers,
12 Pitmen,	2 Waterboys.
3 Locomotive Enginemen,	

REPAIRS OF PLANT.

1 Foreman,	1 Car Repairer,
10 Trackmen,	1 Blacksmith,
1 Machinist,	1 Blacksmith Helper.

PIT PUMPING.

2 Pumpmen.

FEEDWATER SUPPLY.

1 Pumpman.

DRILLING AND BLASTING.

16 Laborers,	1 Foreman.
--------------	------------

GENERAL EXPENSES.

1 Superintendent,	4 Watchmen.
1 Timekeeper,	

PLANT EMPLOYED.

2 Bucyrus Shovels,	3 Pumps.
24 Thatcher Dump Cars,	

The daily average output per shovel for this month was but 440 cubic yards.

The contractors then gave up this section and the work has been recently awarded to F. C. Weir of Cincinnati.

The plant now stored on this section by Ricker, Lee & Co., consists of one "A" frame and two Bucyrus steam shovels, one Otis steam-shovel, four large locomotives, three miles of standard-gauge track and thirty Thatcher air dump cars. These cars are 11 feet 9 inches long, 8 feet 3 inches wide and 2 feet 6 inches deep, holding 9 cubic yards, struck measure. They weigh about 17,600 pounds and are designed for a 40,000 pounds capacity.

SECTION "G."—GAHAN & BYRNE, CONTRACTORS.

The material in this section consists of loam, soft and hard clay and some hardpan in the west third. A wheelscraper force removed

Figs. 6 and 7 omitted.



FIG. 8.



FIG. 9.



FIG. 10.

For Figs. 11, 12, 13, see folded insert sheet.

the top 9 feet during 1894. About a year ago a Barnhart steam-shovel was installed at the east end, loading small Peteler cars, drawn by horses. These cars are 6 feet long, 4 feet 3 inches wide and 1 foot 3 inches deep, holding $1\frac{1}{10}$ cubic yards struck measure. This method was made necessary, as this end of the section is the south line of the Santa Fé right of way, which line makes an angle of $21^{\circ} 40'$ with the center line of the main channel. At a point where the outer foot of the slope of the proposed spoil-bank clears the Santa Fé right of way, a plant designed by Mr. Lindon W. Bates was installed in May, 1894. Fig. 4 represents the modified design; the machine was built with two, instead of three original belts. The weight of the load holds the belt down at the bottom of the slope. These belts are 22 inches wide, the pit belt being 450 feet and the spoil-bank belt 500 feet long. While demonstrating the economical efficiency of this plant, the spoil-bank belt is being carried on a temporary timber trestle. The steel truss, shown on the blue print, is now being erected. It weighs 50,000 pounds. The belt performs its work in any weather men can work.

However, the pit must be kept dry, as the belt stalls when loaded with mud or wet material. This plant is planned to remove the upper half of the section. The daily average output per working day has been as follows: The time from May until September was consumed in installing plant, digging a pit, and loading the belt by manual labor, and experimenting; in October, 777 cubic yards per day; in November, 920 cubic yards; in December, 313 cubic yards; in January, 319 cubic yards. Frost and frequent breakdowns reduced the output for December and January. Figs. 5, 6,* 7,* 8, 9 and 10 illustrate the plant in various positions.

This plant consists of a 60 horse-power Toledo steam shovel, a 120 horse-power granulator, and a 50 horse-power power car, driving the belts. The force employed is divided as follows:

BELT FORCE.

2 Foremen,	12 to 16 Pitmen and Slopers,
1 Engineman,	1 Dumpman,
1 Fireman,	1 Beltman,
3 Carpenters,	1 Oiler.

GRANULATOR FORCE.

1 Foreman,	1 Leverman,
1 Engineman,	1 Hopperman,
2 Laborers.	

SHOVEL FORCE.

1 Shovel Engineman,	1 Fireman,
1 Cranesman,	2 Pitmen.

* Figs. 6 and 7, showing merely other views of the same plant seen in the same direction, are omitted. —*Secretary, Ass'n of Eng. Socs.*

GENERAL FORCE.

1 Coal-passer,

1 Coal-cart and Driver.

To remove the lower lift, a steam-shovel and incline plant is now being installed. This plant will follow the Belt. The next view, Fig. 11, shown, is a general plan of this method. The shovel works cross-wise and loads the alternating cars carried by the incline. This method and incline were designed by Mr. J. W. Page, the contractor's engineer. A few of the advantages of this method may be mentioned. As the incline travels the full length of the section but once, only two miles of track-laying is necessary. The engine-man, being placed in the power-car ahead of the incline, and near the top of the slope, is enabled to see the cars in the pit and on the tipple. The next view, Fig. 12, shows the detailed plan of the incline. This structure weighs 54,000 pounds. The car, when loaded, weighs 15,000 pounds. The strains were carefully computed and checked. A new feature is the double, large and small counter-balance for the tipple. This arrangement insures rapid tipping, without heavy shocks.

SECTION "H."—GAHAN & BYRNE, CONTRACTORS.

The material in this section is similar to that in section "G," with less hardpan. A large wheelscraper force removed the upper four feet during 1894. During last November a Barnhart steam-shovel, loading Peteler cars, drawn by horses, was installed in the triangular west end of the section. Where the full width of Sanitary District's right of way is not interfered with by that of the Santa Fé Railway, a pit was excavated by wheelscrappers, during July, for the Hoover-Mason conveyor. The strike of last summer seriously retarded the delivery of material for this machine. However, by September 25th, this machine began removing material, using one plow and thirty-four shovelers. The wheelscraper pit was 11 feet deep, and this method was adopted in lowering the pit to grade. By October 15th the conveyor pans and carrying track were extended and lowered to the bottom of this pit. Some time was then consumed in properly shaping the pit and adjusting the manner of hitching the plowline to the plow in its various vertical positions. The next view, Fig. 13, illustrates the general plan. It represents the size of the structure and the manner of supporting the track, which carries the continuous steel pan conveyor over 1300 feet in length. The pans are 4 x 4 feet, hinged on 2-inch axles with 12-inch wheels. The ends of the axles have $\frac{1}{2}$ -inch holes filled with dope, under the pressure of brass coil springs. This makes the conveyor self-lubricating for a period of one week. The axles are connected by two eye-bars, tested to stand a strain of 40,000 pounds. The speed of the conveyor is

Spoil Bank



Bottom 110 Feet

100 ft. 0 in.



Double Row of
12 ft. 0 in.

Spoil Bank

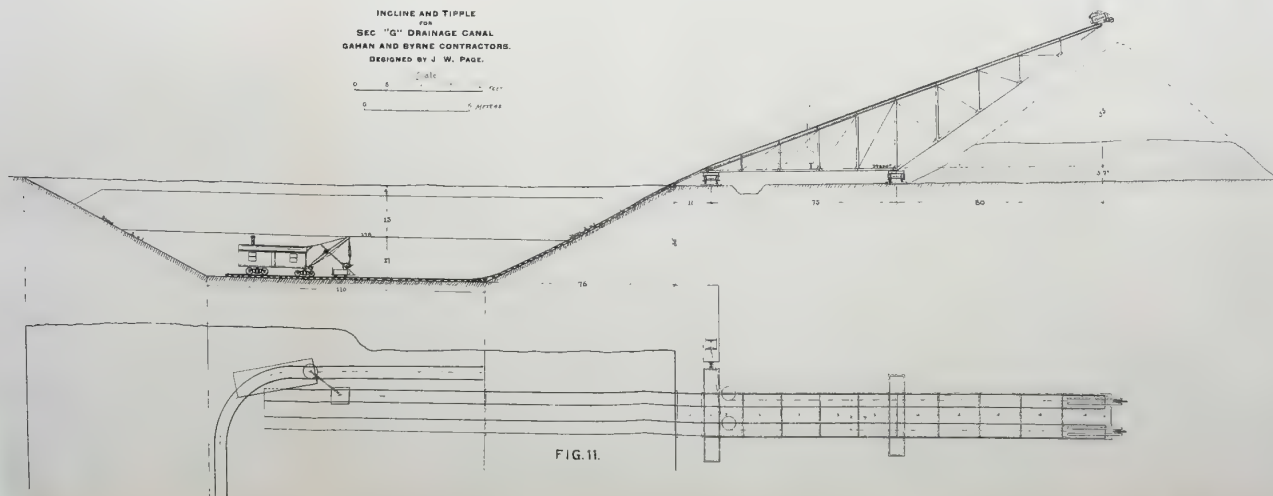
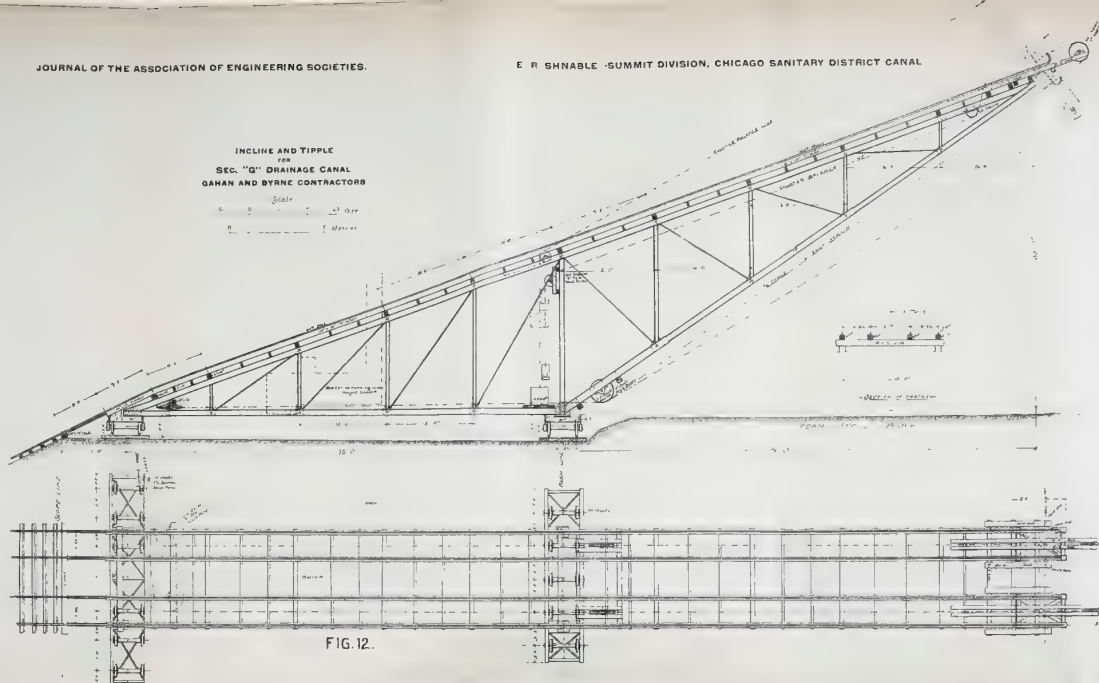


Fig. 14.

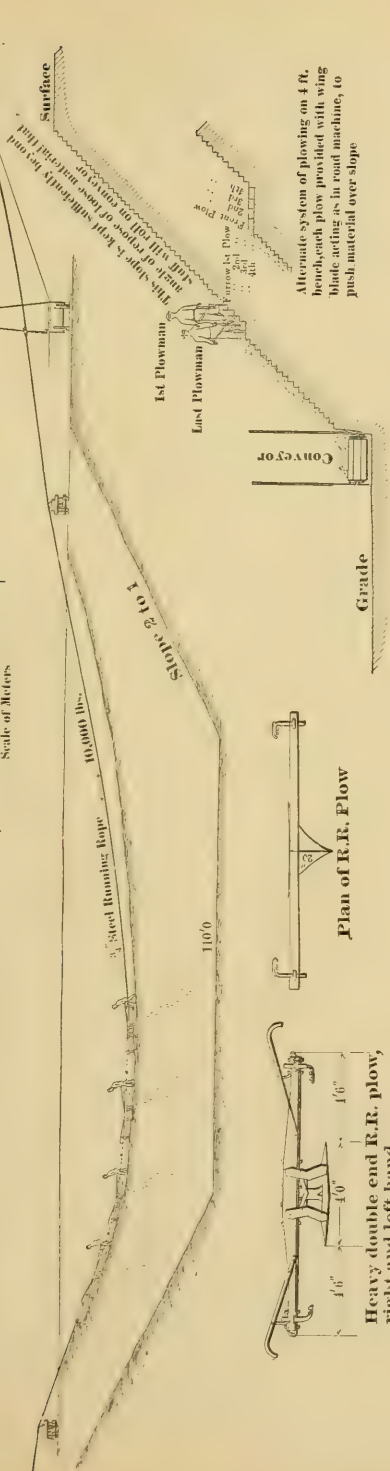
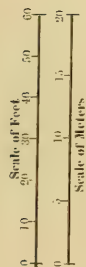
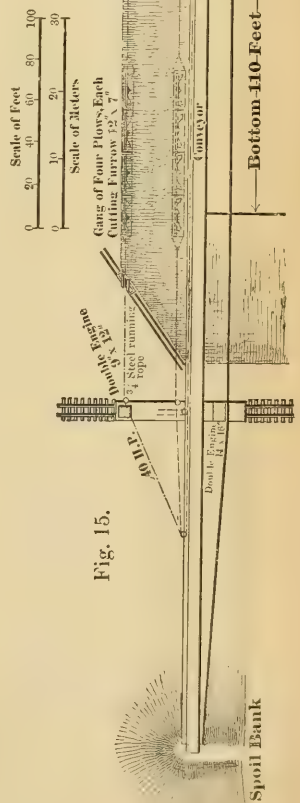


Fig. 15.



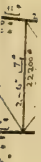
120 feet per minute, and weighs 125 pounds per linear foot. The power, from a double 14 x 17 inch engine, is transmitted by a double manilla rope drive to the gearing at the ends. Two boilers, of 150 horse-power capacity, carried on a separate car, supply the steam for the plow and conveyor engines. This part of the machine operated with remarkable smoothness, due to the perfect design and construction of its parts. However, an unfortunate accident occurred November 8th. The cross timbers, which support the track and conveyor, were rip-sawed to allow the diagonal wind braces to pass by them. The timber over the car carrying the long arm was found to be defective. Until it could be replaced a jack was put under the middle of it. While moving up the machine the jack became loosened and fell. The pans, being loaded heavily at the time, suddenly broke this timber in two.

The sagging conveyor and its load, the span being doubled, broke the next timber. This performance was repeated and the next timber was broken. In the meantime, the wind braces were carried away, and when the falling conveyor struck the lower struts, the stability of the truss was destroyed. The north arm then collapsed. Arrangements were immediately made to repair the damage. Just as the repairs had been made the seventy-mile-an-hour hurricane of January 21st came, striking the machine broadsides. Although the car wheels were blocked with 4-inch chocks, the machine started to move before the foreman in charge realized the violence of the gale. As the machine stood over a pit with its almost vertical face against the wind, a sufficient upward pressure must have been exerted to reduce the holding friction of the blocking.

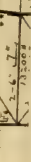
The machine ran off of its tracks, the heavy steel cars were buried in the ground, tripping the points of support and thus toppling over the whole structure. The main truss landed on its side, sustaining very little damage, while the two arms were hopelessly wrecked. The machine is to be rebuilt with but one arm, and will take out the lower half of the section. While being rebuilt, an incline similar to the one described on Section "G" will remove the upper half. This, popularly-called "cantilever conveyor," attracted unusual attention, owing to the boldness and magnitude of design. This, with the careful working out of original ideas, the exceptional ability displayed in its construction, make the accidents, occurring before the economic efficiency could be determined, more than unfortunate. Messrs. Gahan and Byrne fully deserve the high esteem of the engineering profession, by risking their time, money, and reputation, while encouraging such efforts of its members. The next view, Fig. 14, shows a cross-section of the pit and the manner of loading the conveyor with plows. It also shows an elevation and plan of the double-ended plow used. The use of four small plows was first contemplated, but up to the time of the accident, only



STR.



Height

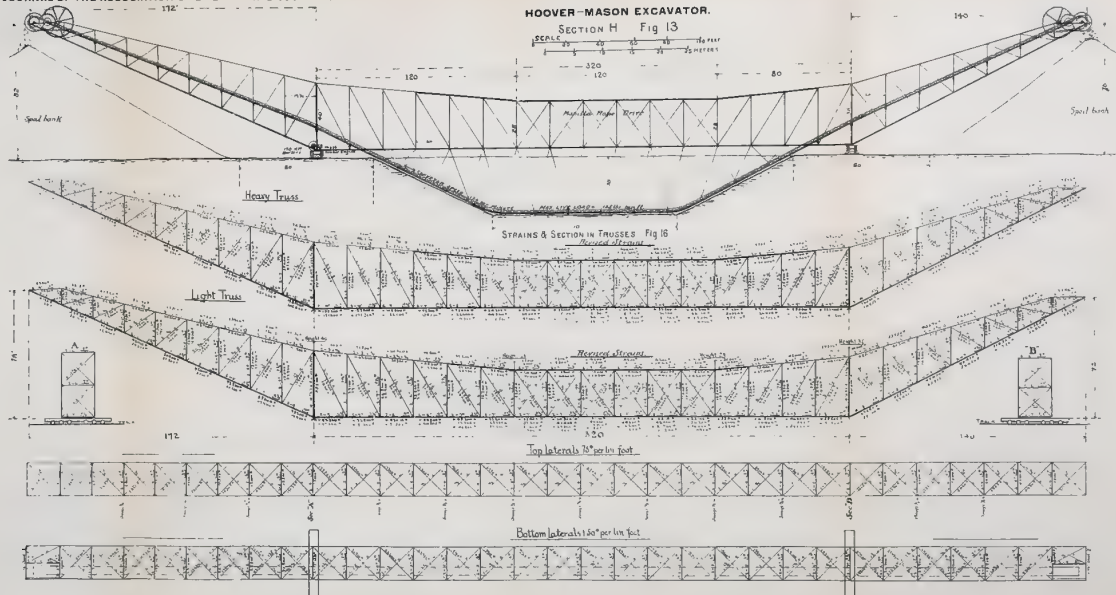
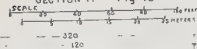


Shore/Support



HOOVER-MASON EXCAVATOR.

SECTION H Fig 13



For Fig. 16, see folded insert sheet.

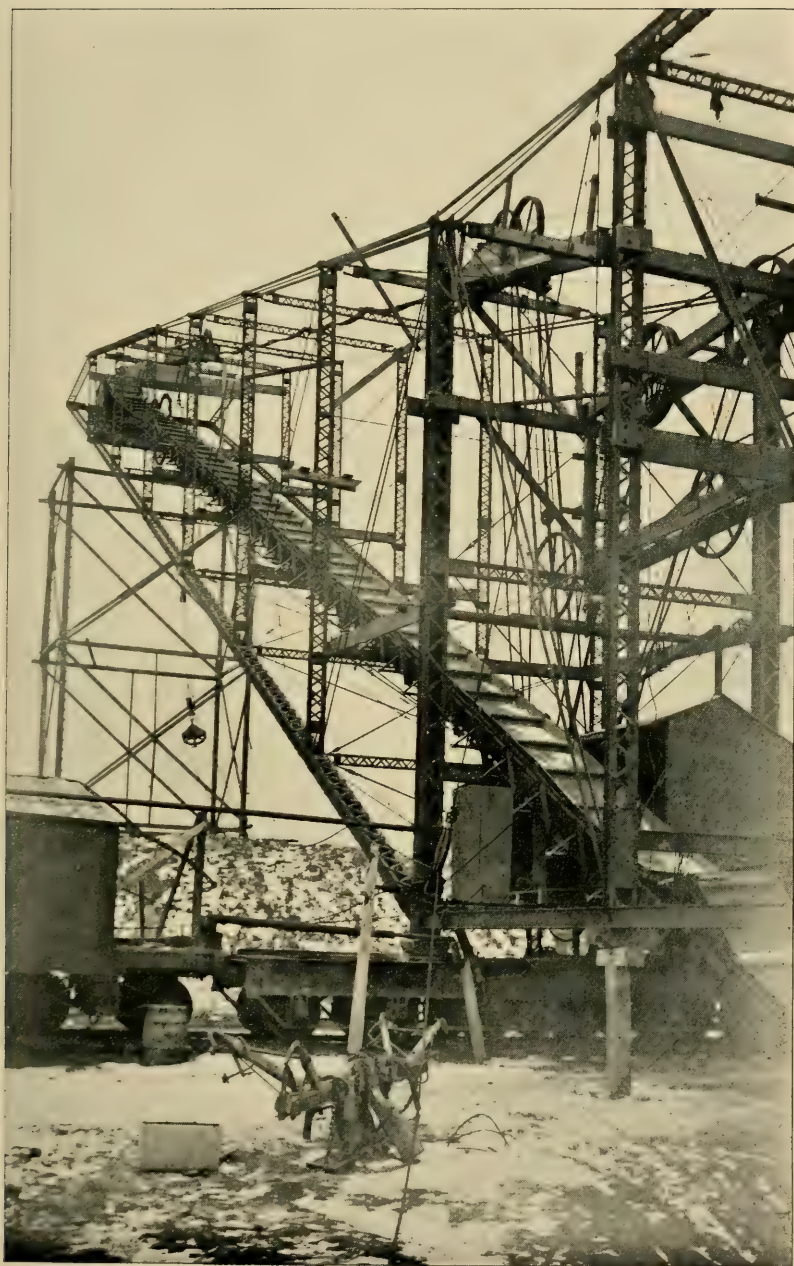


FIG. 17.



FIG. 18.

one was operated. This plow cuts a furrow 7 inches by 20 inches and 200 feet long in one minute, or 4,321 cubic yards in ten hours. Allowing for reversals, changing of hitch and minor delays, the efficiency of one plow can be safely assumed to be 3,000 cubic yards per day. The power from a 10 x 12-inch engine, applied to the plow line is 10,000 pounds. As the plow works down the face of the pit, the pulling line is gradually moved parallel to itself and toward the conveyor. The plow line closely approaches a catenary curve, and the sheaves, through which it runs, are lowered as the plow descends. The points of the plow are slightly turned both downward and towards the face of the cut, giving a bite in two directions. The four adjustable shoes, shown in plans, counteract this tendency sufficiently to keep the plow steady. The hitch on the plow beam is adjustable, and is made by a half-hitch in a chain. This movable hitch is necessary owing to the change of direction of the pull. The next view, Fig. 15, is a plan of the pit and shows the movement of the plow line and sheaves. The next view, Fig. 16, shows the strain sheets. The next two views, photos Figs. 17 and 18, show the conveyor as built.

CONCLUSION.

In conclusion allow me to thank Professors Hatch, Stine, and Snow, representing the Armour Institute, for their generous kindness in preparing the numerous slides, exhibited to-night by means of an electric lantern, especially installed for this occasion.

SHOULD OUR PATENT LAWS BE ABOLISHED OR MODIFIED ?

BY JOHN RICHARDS, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read July 6, 1894.*]

THE problem of personal property in inventions, which is in a sense included in the question presented for this evening, has been the subject of profound investigation for more than a century past, and the rightfulness of such property has been defended by statesmen and jurists of all countries, so that a discussion of the expediency of abolishing the Patent Laws is not likely to do much good, but rather to be a waste of time and effort.

Patent laws exist in all civilized countries, Holland excepted, and countries that have abrogated their patent laws have again instituted them. Among these is Switzerland, where we have reason to believe that legislation and national economy have their highest development at this day. Besides, the tendencies of our time do not point in the direction of restricting monopoly, but, on the contrary, to its extension in various forms. This is true of nearly all civilized countries, and especially of the United States, where not only the powers of legislation but their construction is warped to promote private interests in a greater degree than at any previous time. Competition and free commerce are hampered in a hundred ways, and among all the privileges permitted or promoted by law, none are so harmless, or have so much to claim in the way of equity, as the questionable monopoly permitted to inventors who obtain patents.

In the case of most of the patents granted on mechanical inventions the object is to prevent imitation and protect manufacturers, and the amount added to the selling price of commodities by reason of such patents is commonly very little and sometimes nothing, but there are other privileges, granted without the qualifying conditions that attach to patents on inventions, that raise the price of commodities in some cases a hundred per cent., and in many cases fifty per cent., such grants or privileges being absolute, and not even binding the beneficiary to turn over to the public at the end of seventeen years a consideration presumably equal to the privilege received.

The natural right of a person to exclusive use of what he may have

* Copy received April 25, 1895.—*Secretary, Ass'n of Eng. Socs.*

discovered or invented, or, in legal terms, the property in invention, cannot be questioned upon any other grounds than the abridgment of some right of other persons or of the public, and such abridgment could be proven only by one of two facts: that the invention or discovery was not new and original, and that the public could by other means have acquired the same advantage sooner and on better terms.

A patent is in its nature a contract between an inventor and the public, in which it is stipulated that if the patentee will file in the archives of the Government a complete description of his invention with drawings that will enable others to understand, make and use his invention at the end of seventeen years, he shall for that length of time enjoy a monopoly and exclusive use of his discovery.

This grant is not absolute, but is conditional on the invention being new, and that it does not interfere with rights and privileges already existing. It is also qualified by other conditions, such as the perspicuity of the description and its completeness, also the language employed in defining the scope of the patent, so that, on the whole, letters patent in this country seem in comparison a tame kind of monopoly, and indeed is only a reasonable bargain with the principal stipulations against the patentee, who must maintain at his own expense, and risk all the conditions imposed upon him by the grant.

These remarks upon the nature of patents for inventions are necessary in order to properly consider the practical working and the abuses of our patent system, to which the question of this evening seems to be directed.

The extent of the influence of patents on our industrial interests in this country is not known, or suspected even, nor is the methods of that influence very well understood. There are very few manufactures started at this day that are not founded on some kind of protection. This may be by large aggregations of capital, and an organization that permits cheap production; by combinations of a number of manufacturers to control prices; by secret processes and special skill acquired throughout generations, and by patented rights that secure to the manufacturer the exclusive use of certain implements, processes or products; also by a combination of two or more of these means, often all of them, in the case of extensive manufactures. Among these means of founding and protecting manufactures only two are open to a poor man, or a small manufacturer, the secrecy of processes and patents, as before said, and in these rest the greater share of new ventures in the skilled industry of our country.

It seems a strange proposition to oppose monopoly with monopoly, but in this case it is done. It is almost the only means left to a people struggling against vast aggregations of capital and resources that are dragging us each year nearer to socialism.

If, in this city, one of our large iron works had free use and control of all the inventions in that branch of mechanic art, there would soon be but that one works here, and the owners would paternally care for all the people employed or connected with that industry. It would be the same thing if extended to other interests, and the division of industry would cease in the various branches now carried on. Opposed to this concentration is our patent system. It stands almost alone, but its power is great, and with intelligent and honest administration of our laws it insures in some degree a division of our manufactures, and permits people without large capital to carry on business. Whether it is desirable to narrow individual enterprise, and concentrate our industries in large combinations, is another phase of the subject that cannot be discussed here.

The agency of patented inventions in developing and improving processes and products is the argument commonly set forth in support of a patent system. Whatever this influence may be it is of less importance than the one just mentioned. The "nature" of what we call progress at this day is much less important than the "manner" of it and the social effects resulting therefrom, hence this point may also be passed over here.

Reverting now to the modification of our patent laws, there are several serious impediments to reform. There is first the difficulty of securing the required attention and service in Congress to this or any other matter of national concern. There is no one to promote new measures of the kind. The country at large has no Representatives or Senators in Congress. These all represent the interests of their especial districts, states and constituents, also themselves, and there is no direct incentive to inspire legislative effort on behalf of Federal laws of general and equal application.

The Patent Bureau at this time has not more than one-half the office room required, but has a credit of between three and four millions of dollars in the patent fund, a surplus of fees paid in by inventors, and so long as a requirement so obvious cannot engage the attention of Congress there is little hope of amendment of the patent laws. Other kinds of grants and monopoly require all its time and energies.

Within twelve days past a duty of \$2.07 per thousand has been assessed on blasting caps, a little more than the worth and price of the caps. There are two makers of such caps in this country. They have received a patent without promise of turning over their processes and inventions to the public at the end of a term, and have the farther advantage that the Government in fact collects the royalty from the miners and turns it over to these two makers of blasting caps. This is mentioned as the kind of patents that Congress is just now engaged upon.

Another impediment is the want of understanding the nature of letters patent for inventions as a part of the National economy. The subject has engaged the attention of the most eminent men in all countries where patent laws exist, and one has only to look over some legal decisions to see the great complexity of the subject. It is one that must be viewed in the concrete, and is so mixed up with industrial and commercial affairs of the country that not one congressman in fifty could vote intelligently upon a modification of the laws, much less draft and promote new measures.

Mechanics and engineers do not often go to Congress, and happily are not often concerned in what we call politics. The late President of the French Republic is almost the only engineer that has ventured into national administration. Col. Turretini, Mayor of Geneva, and the present Mayor of San Francisco, are the only others that can be called to mind, and there is little wonder at the difficulty of dealing with patent laws in the popular legislature.

These remarks indicate the temerity with which suggestions should be entered upon here, but the present remarks would be incomplete without some criticism of the existing law. Our patent system, while it has many excellent features compared with that of other countries, is anomalous in respect to what is called the examination of applications for letters patent. There is examination, as the term applies, and to this there can be no objection. On the contrary, it is a great aid to the inventor and his attorney, saving searches that would be expensive, and even impossible, with the usual resources at hand, but the functions of the examining officers do not stop with their search. They do not, as an engineer, lawyer or other professional man would do, endorse the facts and their opinion on the application, or enter these upon the record, but are obliged to exercise judicial functions, and decide the case on their own evidence; that is, "reject" the application if in their opinion the alleged invention is not new. Such a perfunctory duty must be as disagreeable to the examiners as it is illogical and unjust to an inventor, because it assumes the power of destroying a patent with no corresponding power of confirming it. This is left for the inventor to do after the patent is granted, and, no doubt, should be, but on what grounds should a primary examiner reject a patent when he has no power to confirm it?

It is placing on him perfunctory duties that implies his want of ability to arrive at and record a professional opinion; puts him in the position professionally of a routine clerk, and officially in the position of a judge.

If the examiner's views were endorsed on the record, and the applicant had the right to appeal or call for further opinions of higher officers up to the Commissioner, the procedure would be logical and just

Patents would then be issued with a full record, and at the applicant's risk, as is done in most other countries, where repeated and invalid patents are less often granted than they are here. As it is now, a patent when issued bears no record of the office procedure, but no one thinks of purchasing a patent without sending for a transcript or what is called a "copy of the file," in the case. This should be printed with the patent at its issue, so that anyone concerned in the matter would have the whole record before them.

There are many other reasons against rejections or the judicial functions of examining officers, that are engaging an increasing amount of attention in this country, and will no doubt in the end lead to some change beneficial alike to the Bureau and to inventors.

Time will not permit a notice of some other points that could be profitably presented before the Society at this meeting, and but one other will be named,—respecting trade marks. The present law on this subject seems to be founded on the assumption that a trade-mark, registered in the Patent Office, is an attribute of the goods to which it is applied, and not a personal matter relating to the firm or company that applies for registry. The applicant is called upon to define particularly the class of goods and also the articles in that class, to which the trade mark is to be applied.

As a matter of fact, obvious to any one, a trade-mark is a short way of endorsing the name of a firm or business on goods without using personal names, that may be changed, and in this sense has no particular relation to the articles on which it is marked or stamped. The purpose is to set forth that a particular person or firm produced the goods, and the laws of registry should certainly be based on that fact and not on the assumption that the trade-mark is an attribute of the goods themselves.

Having consumed the allotted time, and perhaps more than was intended, there is but one thing more to add, that is, some mention of the honest and faithful administration of the Patent Bureau. It ranks first and stands with the Coast Survey Office and Army Engineer Corps, in this respect. Thirty-five years of continuous intercourse in one way or another with the United States Patent Office has not, but in two instances, brought to knowledge the least charge of misconduct in that Bureau, and in both these cases the charges were confined to the chief officer.

Our patent system may have faults, and naturally falls under suspicion sometimes, by those not acquainted with its organization and history, but such suspicions are groundless, in so far as the long experience before named has disclosed.

It is respectfully submitted that any abrogation of the patent law is not only inexpedient but impossible. That patent grants for invention are equitable and the least harmful among many privileges conferred by

Federal laws, and that the abuse of patent privileges is less than in the case of other laws creating privilege and inequality; also that their improvement is both possible and probable when Congress can be forced to give some attention to National affairs.

DISCUSSION.

MR. CARSON.—I would like to ask how it is that some people get information of patents in the Patent Office before those patents are granted? In Cincinnati, an association called, I think, the American Patent Association, sends out letters to different parties advising them in regard to the status of their applications.

MR. A. B. BOWERS.—I think this information can be obtained only through the attorneys employed to present the case to the Patent Office, not through the Patent Office or any one connected with it.

Q. Is an application on file open to public inspection? For instance, would an application for a patent on a Broom machine be on file under that heading?

A. Any person bringing a power-of-attorney from an inventor can examine the application. No other person can see it except the examiner.

When an application is made for a patent, the examiner immediately compares it with all of the patents issued on the same subject in the United States, Great Britain, France and Germany, and, in cases where the inventor makes broad claims, the examination extends to still other countries, and in some instances libraries are ransacked, encyclopedias, dictionaries, technical journals, common newspapers, and the practice of those engaged in the business to which the invention is most nearly allied.

Claims for patents are examined very carefully, and any claim that the examiner thinks will be rejected by the courts, if a contest should arise, is rejected in the Patent Office. If the applicant is not satisfied with the examination, he can appeal to a Board of Examiners who have the power to review the action of the Chief Examiner in charge of the application. If the applicant is dissatisfied with the decision of the Board of Examiners, he can then appeal to the Commissioner of Patents. He has two appeals. In some cases the Board of Examiners reverse the decision of the Examiner, and sometimes they affirm it. Decisions are sometimes reversed by the Commissioner. But the Examiners, in the several divisions, are men who have had a great many years' experience in the matter, and are well posted in the particular branches they are engaged in. It is very seldom that the decision of the Chief Examiner

in any department is overruled by either the Board of Examiners or the Commissioner, although it is sometimes the case when good reasons can be presented.

Usually a claim for an application consists of a good many claims. Whenever a claim is finally rejected and you are notified that an appeal will now lie to the Board of Examiners, it is about as well to stop there and save time and trouble, unless you can show very clearly that the Examiner-in-Chief is mistaken, and it is not easy to do that. I know in the department where I have had applications, that when I got a final rejection by the Chief Examiner, my attorneys have told me that it was not worth while to appeal from the decision, and I have accepted their advice.

PRESIDENT GRUNSKY.—One of the principal points in Mr. Richards' paper seems to be the fact that many of our manufacturing establishments rely upon the protection of letters-patent for their very existence and conduct of business. Any information on that subject, I think, would be of interest. It is somewhat new to me. I was surprised to hear so broad a statement.

MR. G. W. DICKIE.—I do not know that I have reached the stage when I would say that patents ought to be abolished, but my opinion is a decided one that the patent laws ought to be modified very thoroughly.

A patent is granted in this country if the Examiner can find no previous patent covering the subject. The examiners are not qualified to pass upon the newness of the subject; they are not qualified to pass upon the question as to whether it is an invention at all or not, but the examination has simply led to the determination whether this thing has already been patented. Therein, I think, lies the difficulty with patents. There are so many people who obtain patents for things that are not new, and that are not inventions; in fact, a very large majority of them are in common use every day; and there is no manufacturer of mechanical articles but is subject to a great deal of annoyance and trouble and hindrance in his work through the interference of these patents of things that are not inventions at all. This morning I got an injunction saying that I must not make any more piles of square timber with a sheathing of redwood, with felt between the redwood and the timber, because it had been patented; patent dated January 1, 1889. I told the party that we had been making these piles since 1883. He said, that made no difference; that we could not use them any more, or make them any more. I told this party that his patent was not a new thing; we did not consider it new when we used it; it was an old thing and quite familiar to all of us. He said, "You have no patent for it, and therefore you can't make

it." It is this ignorance on the part of inventors that gives the most trouble. We are continually beset with that kind of thing. Sometimes, rather than go to the expense of a lawsuit, we will pay something to get rid of the interference.

Then there is another class of patents that are granted for things that are in common use, and which affect patents already granted. This kind of patents are a gross injustice to all those engaged in mechanical manufacture. As some of you know, several years ago I designed a hydraulic dock for the Union Iron Works. There were a great many things about it that were practically new in dock construction; and, in fact, I may say here that every day, in a large engineering establishment, there is more real invention in regard to details of work than you will find for a month in the whole range of patents. In designing this dock I did not protect any of the new things I introduced in it. Some three years ago the Government engineers wanted to adopt my principles at the Cascades, and they came around and asked me if I would not make drawings for this slip. I had some drawings made for them simply as a matter of courtesy, which they very nicely acknowledged in the Government report. The draughtsman, while making the drawings, thought that in manipulating the valve it would be better to have the screw move through the nut instead of the nut through the screw. I had no objection, and I thought in some cases it might be better. Some two or three months after that I saw the publication of a patent that this man had taken out, as applied to hydraulic docks.

These things are very aggravating. He gets his patent because it had never been patented before. If the dock years ago had been patented, he could not have got the patent. And this kind of thing goes on every day, and those who have to bear it get very much irritated over the patent question.

I am against patents for the reasons I have stated. I took out a good many patents years ago, but I came to see the error of my ways in that respect and have given it up.

If there could be some way by which real inventions and real inventors could be rewarded without the manufacturing community being saddled with so much of this patent business, I think it would be a grand thing and a move in the right direction. If it were possible to have some kind of commission, composed of mechanics, to whom inventors could submit their inventions and let them decide whether the inventions were new, not whether they are patentable, it would be much more practical. There is all sorts of maneuvering and tricks to find something that is patentable, and therein lies all our trouble. It is not a fact that engineers are opposed to the rewarding of inventors for real inventions, but it is the multitude of tricks they are opposed to. A great many of the

so-called inventions are backed up by an appalling amount of ignorance. Probably more patents have been taken out on steamship propellers than any other device. Many of these propeller-patents are taken out by farmers. You see an old hayseed coming along with a roll under his arm, and he has a new propeller sure as fate. I know them by instinct.

I practically indorse all that Mr. Richards has said, but he does not touch the question as it touches the manufacturer. I do not think Mr. Richards is right when he makes the statement that most of the large manufacturing establishments are based on patents. I think most of the engineering concerns in the world are those that you never find mentioned in connection with patents.

PRESIDENT GRUNSKY.—I understood Mr. Richards' paper to state the reverse ; that it was the smaller institutions that owe their existence to patents, and the larger manufacturing establishments are less dependent upon patents.

MR. DICKIE.—That may be the sense of the paper. There is no doubt but a very large number of small manufacturing establishments are founded on patents, and some of them are founded on inventions of great utility, and they deserve all they get out of them. But these are but a drop in the bucket compared with the deluge of useless patents that are not inventions.

I would like to make this distinction understood. What I am opposed to are patents, not inventions. I have talked with hundreds of engineers on this subject, and the general opinion among them is, that if we could avoid this deluge of worthless patents and reward the inventors of useful things, then the Patent Office would be of great benefit to the mechanical community.

MR. BOWERS.—I agree with the last speaker in pretty much everything he has said. There has been an immense number of worthless patents issued by the Patent Office, and are being issued every day. There are a host of people who watch the official *Gazette*, and the moment they see a patent for an invention that they think has merit, they immediately start in to devise some trifling modification and take out a patent for that, and, in making their application, they will make a drawing of the full invention. After having secured a patent for that little detail, they will go to some one that is not up in patent matters and show him the drawings, and say they have a patent for that invention, and nine people out of ten will take it for granted that the patent covers the invention shown, while the contrary is the case. The drawings shown of the patent are covered by the prior patent, and the subsequent patent covers only some trifling detail.

Then there are persons who get a claim on useless patents. It is astonishing what a number of worthless patents are sold, and the amount of money that is made by people who are not inventors, but who will devise a trifling modification of an invention and secure a patent for it.

There is another thing I wish to mention which I think ought to be incorporated into our patent laws, or into the practice of the office. A person will see a patent that covers a good invention, and he thinks he can make some small improvement on it. If the patent is a new invention, and has a broad claim covering all mechanical equivalents—or so broad that the art or the matter covering the patent cannot be practiced without violating the patent—a person may design some little device differing slightly from the original and claim that it is an improvement on the original, and the Patent Office gives him a patent for this improvement. Now then, that improvement is subject to the original invention, it is covered by the original patent in this sense; that it is an infringement on the original patent. While it may be a good improvement, and the patent may be valid, still it cannot be used by the person making the improvement, because it is covered by the broad claims of the original invention. Now, in all such cases as that, a patent should be granted to the inventor, and he should be allowed to use it. As the law now is, he has no right to use it himself, because it is subordinate to the original invention. A great many people think that if they take out a patent for anything, then they have the right to use it. This is not the case with the class of patents I have just mentioned, and they will not have a right to use it until the original patent runs out.

The point I had in view was this: That in all cases where a patent is subordinate to a prior patent, it should be so stated in the patent itself, so that parties buying the invention might know that they would have to also buy the right to use it. There are a great many of such patents issued, and they are sold to parties who think they have a right to use them, and who honestly and in good faith go to work to operate under the patents and then find them subordinate to prior patents. All this could be largely avoided by stating in the patent itself that it was an improvement on another patent, subordinate to it and subject to the rights of the owner of that patent. This would save a great deal of litigation, and it would save thousands of innocent parties from investing money in that which they have no right to use after they have bought it.

PRESSURE AND IMPULSE IN MOTIVE ENGINES.

A Look Into the Future.

BY JOHN RICHARDS, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read January 4, 1895.*]

WHEN a man of discerning tendencies has spent thirty to forty years engaged in what is called constructive engineering work, in an advanced environment, and when he has thus learned to understand contemporary practice, he is in position to render the highest possible service to the world by forecasting the future.

To do this to the best advantage he must withdraw from the activities of practice, and from personal interest in any particular thing or branch, and must impartially survey the whole field, weighing, measuring, and comparing, and considering what the trend is and what the future will probably bring forth.

Such prognostication is of the very highest value. No other contribution to the world's industry can have more value, even from an intensely practical standpoint. In fact, a great share of the highest human effort is devoted to prying into the future, and in endeavoring to find out what its future wants will be, and what is likely to supply these wants most acceptably. This prospective spirit is the essence, so to speak, of both commerce and manufacturers.

The most interesting and important part of such forecasting relates to physical discovery in the technical arts, and notably in those involving the employment of motive power.

These remarks are suggested by a letter lately received from Mr. Charles Brown, C.E., of Basle, Switzerland, containing some forecasts in respect to engineering matters.

Mr. Brown is one of the most eminent constructing engineers now living. This claim has authority far beyond the writer's opinions, but he can add the fact that for twenty years past he has watched with interest and profit every work and opinion emanating from this distinguished engineer. After a successful career, extending over an average lifetime, employed in constructing work as diversified perhaps as has ever fallen to the lot of one engineer, bringing to bear thereon a remarkable natural ability coupled with education and training of the highest order,

*Copy received April 25, 1895.—*Secretary, Ass'n. of Eng. Soc.*

he has now turned back to look over the field passed through, and to draw from it conclusions that deal with the future.

I have no authority to introduce Mr. Brown's name here, and none to quote from his letter mentioned, but it seemed necessary in the present paper to shield myself behind the opinions of one whose views are entitled to much more weight than my own.

Some of Mr. Brown's views, as I gather them from one or two paragraphs in his last letter, and hinted at in previous communications from him, may be stated in the following propositions:

(1) The utilization of the force of fluids, elastic and inelastic, will in the near future be mainly by impulse instead of pressure.

(2) The impulse of fluids, elastic and inelastic, will be utilized by means of rotary motors.

To render these propositions plainer, and to connect them with familiar practice, I will remark that they mean that steam engines, pumps, and blowing engines, like water-wheels and water engines, must abandon pressure upon pistons, and substitute the action of impulse upon wheels.

This does not mean that a revolution is suddenly to take place, but that the future tendency is to be in the direction, or, as we may say, is in that direction now, and to a greater degree than is commonly known or supposed. The proposition must also exclude special appliances, both for elastic and non-elastic fluids, and be confined to what may be called common pumps and motors.

I am not quoting Mr. Brown's words, or paraphrasing them, but am, to some extent, guessing at his opinions by inference.

Before speaking of the subject in its practical aspect, and as connected with modern engineering practice, some generalization may render it more clear.

Machinery to utilize the gravity of water in descending from a higher to a lower level; machinery to overcome the gravity of water and raise it from a lower to a higher level; and machinery to utilize the expansive force of water converted to steam, or, in other words, water-wheels, steam engines and pumping machinery, with their attendant elements, constitute a large share of what a mechanical engineer is called upon to study and deal with at this day, and it is to these the propositions before named relate. I will not detain you by statistics of the amount of steam- and water-power in the world, or its relation to transportation, travel, commerce, manufactures and even the social conditions of our times. This is too well understood to call for remark.

In the descent of water we have the choice of two methods for utilizing its gravity—pressure or impulse. The first represented by water-pressure engines, gravity or overshot wheels, and pressure-turbine wheels,

such as those of Fourneyron, Jonval and the American types of inward discharge wheels, all operating by pressure caused by obstruction to flow, or, as we may say, receiving pressure directly. The second, or impulse method, represented by the Atkins, Girard and Pelton wheels, operating from the impingement of jets set in motion by pressure, or, as we may say, by pressure in a second phase of spouting velocity.

The action of water in the case of enclosed or pressure-turbines is not, I am aware, resolved mathematically, as stated above, but this rendering is near enough for the present purpose, which is to show how the two methods of pressure and impulse have in water-wheel practice been contending for thirty-five years past, dating from the first impulse-wheels made by Messrs. Escher, Wyss & Co., of Zurich, Switzerland, about the year 1860. The principal facts of this rivalry will be again referred to.

In steam engines a similar struggle has begun between impulse and pressure. It is young yet, and lacks the history of water-wheel practice, but the future problem is now well before us in both its theoretical and practical aspects, but has not advanced to a place in popular knowledge that permits general discussion.

At this time all popular ideas, as well as nearly all practice, is confined to pressure-steam engines of both the piston, or reciprocating, and the rotary kind, mainly the former, but all operating by direct pressure and maintaining steam-tight running joints around pistons. The construction and mode of operation is too familiar to require explanation.

In the other class of steam engines, the impulse kind, there is employed the efflux of steam-impinging against vanes that move at about 0.55 of the velocity of the steam, or thereabout; for an average 500 feet per second, or 30,000 feet per minute, according to the steam-pressure employed. In some cases discharged on the vanes at the initial or boiler pressure, in other cases expanded before impingement, down to atmospheric pressure, the effect being nearly the same, and as the mass, or ponderable weight of the fluid. The velocity is not diminished, and is even increased at this lower pressure by means we need not inquire into here.

Here we have a strange analogy between the application of elastic and inelastic fluids, between water and steam, and in a change from pressure to impulse action. The same laws apply in respect to the relative velocity of motors, the method of application is nearly the same; in fact, impulse water-wheels have, in some cases, been driven by steam.

The main distinction is in the respective velocities of efflux and consequent speed of the motors. For water we have $V = \sqrt{2 g H}$, and for steam $V = 60 \sqrt{T + 460}$, both in feet per second, or about as eight to one. At this pressure a steam-driven wheel to operate economically would have to attain, as before remarked, a speed of about 500

feet per second, 30,000 feet per minute, according to the steam pressure employed.

Before referring to the tendencies in present practice, and considering what the future may bring forth, I will point out that a first conclusion will be that all these things are amenable to computation, and can be solved mathematically. This is unfortunately not the case. Some of the conditions, and even the dynamic results, may be thus arrived at, and have been in the case of Parson's impulse steam engines, also Dr. De Laval's, but the main problems are of a constructive nature, pertaining to the maintenance of high velocities, balancing, lubrication and the elements of transmission.

Still it must be admitted that but little progress can be made without the aid of computation in verifying and explaining results, in so far as forces and resistances, but, as remarked, the chief problem lies in that branch of engineering we call constructive. For example, a theoretical steam engine would be one of the rotary type, sustaining direct pressure, and moving at velocities not at all attainable in such engines, even if they were a possible machine on other grounds, which they are not.

The strange proportions of parts would never have been resolved as they are found in practice either by inference or computation, but being found, then new light is added by theory; definite rules are arrived at, the direction and measure of inherent forces are made plain, the thermal conditions are explained, but first and mainly must come the constructive idea or design qualified by working conditions so obscure as to defy human skill until tentatively developed by long and tedious experiments, dealt with empirically, often blindly, and no small share arrived at by accident. This has been the common course in the past, and is now to a great extent the path followed, but in some instances progress has been the other way, not from construction, use and experiment, but in attempting to supply mechanism to accomplish certain computed results.

Pressure and impulse steam engines furnish two notable examples of these two methods of development. The first were a constructive and experimental problem throughout three-fourths of their history, before the study of thermal laws became a part of steam engineering. Then by both computation and a higher constructive skill the advance during twenty years past has produced our modern types, approaching nearly to ultimate efficiency for the pressure system as it now exists. The course of impulse-engine development is different. It starts with all the aids that have attended the final work on pressure engines, but on the whole the system or method has in ten years made nearly as much progress as the pressure or piston type did in a century, that is, from a steam consumption of 48 pounds per horse-power down to 14.5 pounds, or high

efficiency for modern expanding engine of the piston type. This matter is mentioned as one factor to be taken into account in forecasting the future and interpreting signs that increase from month to month.

Reverting now to the practical part, and first to water-wheels, we can easily follow the advance made in the impulse type. The first discovery and proposition of this method, so far as I can trace it, originated with Mr. Jearum Atkins, an American, now in his old age an inmate of the Mechanics' Home in Philadelphia. He presented his invention of open or impulse turbine wheels in the American Patent Office in 1853, where it could not be understood, and a patent was refused. He at that time filed in the office a complete analysis of the theory upon which these wheels operate, clear, concise, and to-day one of the most lucid descriptions that can be referred to.

In 1875, twenty-two years later, a patent was granted to him for the same invention; but before this time, about 1860, impulse turbine wheels had been taken up by some of the foremost engineers in Europe, and had become a standard type in France and Switzerland. At the present time, and for fifteen years past, no other form of water-wheels has been thought of there, or in other European countries, for heads exceeding fifty feet.

The practice is very uniform all over Europe, and the number of impulse wheels made must exceed pressure turbines three to one. The great wheels at Niagara are a modification of the Girard or impulse system, more nearly impulse than pressure wheels, the plans being supplied by Messrs. Faesch & Picard, of Geneva, Switzerland, who were among the early makers of Girard wheels.

On this Coast I need hardly say that tangential wheels, a purely impulse type, have displaced pressure turbines for all except low heads, with gain in efficiency, a saving in first cost and in maintenance. The impulse method has in fact been successful in all cases of competition up to a limitation by the volume of water that for constructive reasons renders the system inapplicable for low heads, and when wheels require to be submerged.

The change from pressure to impulse in water-wheels is, however, by no means so great a change as that between pressure and impulse steam engines. The initial velocity of water, or of wheels driven by this element, is the same in both cases, but with steam the initial velocity is changed, as we have seen, as fifty or sixty to one, giving rise to new and extraordinary differences. To make these more plain I will again enumerate with more detail the conditions of operating with pressure or piston engines.

The weight and space occupied by motive engines of all kinds are, as a rule, inversely as the velocity of the "actuating parts," and by such

a rule pressure engines should be fifty times the weight of impulse engines. The running joints or bearings for pistons, valve rods, valves, guides, connections, and so on, consuming from six to ten per cent. of the developed power in piston engines, are nearly avoided in the impulse type, but are to some extent, not known, balanced with losses by air friction on the impulse wheels. The elements of transmission between the piston and crank shaft have at all points throughout to withstand the full measure of strain imparted to the crank pin, not uniformly, but in a series of waves, to so call it, consequently these elements are about five times as heavy and expensive as when the initial movement corresponds to .055 that of the flow of steam. The change also simplifies such gearing.

Vibration, due to intermittent stress and reciprocating parts, is a serious objection and impediment in the pressure system. It calls for ponderous fastenings and foundations that with lavish plans and material, especially in vessels, is only partially successful.

Fly wheels have to be provided to equalize the variable turning moments in all land engines. This function is supplied in vessels by paddle wheels, screws and multiple engines, but a fly wheel of some kind is an essential part of an ordinary piston engine.

We have then in this case a motor moving at eight to ten feet a second, impelled by a fluid whose normal flow is eight to nine hundred feet a second; fifty times the weight, and ten times the space occupied that would be required if the steam could be directly applied. There is, however, one difference that must be kept in mind, that in engines driven by the impulse of steam a certain speed must be maintained, while in piston engines this is variable in any degree.

For most purposes this latter feature is not important, but is indispensable for traction, and we need not look for change in that branch of steam machinery. The same fault would in some degree apply in navigation where variable speed is necessary, as in the case of boats making frequent landings, but not for ocean service.

This difficulty in impulse engines arises from the fact that the flow of steam follows a different law from that of liquids, and is computed as a function of temperature, instead of pressure or head, varying only 35 feet a second between 25 and 100 pounds pressure, and only 10 feet a second between 100 and 150 pounds per inch, consequently speed cannot be controlled by volume.

But outside of all uses requiring variable speed there is left a much wider field for impulse engines, and considering the objections to the pressure or piston system before pointed out, we cannot wonder that men learned in these matters should set about finding out some escape from such sacrifices made to mechanical expediency. I am not able to

name but a few of the eminent engineers who have considered and are engaged in developing the impulse system for steam engines.

First may be named Dr. De Laval, of Stockholm, Sweden, inventor of the centrifugal cream separators, who, to impel these high speed machines, conceived the idea of a steam-driven impulse wheel, operating by the direct efflux of a jet applied on vanes. This, as we believe, was about ten years ago. The object was not efficiency or novelty, but a high initial rate of rotation to avoid transmission gearing. The result was so remarkable as to lead on to further experiments and results until a steam consumption as low as forty pounds per horse-power per hour was attained.

Then the matter began to attract attention, and the Hon. C. A. Parsons began, in England, a series of exhaustive experiments connected with careful computations of the thermal and dynamic conditions attending on the impulse method, and now, at the end of less than ten years, he has removed modern compound piston steam engines in the city of London, and replaced them with steam turbines, or impulse engines. This was done in one of the stations erected only a short time ago, and as Mr. Brown remarks in his letter before referred to, "is a most significant fact." It is more than a year since the editor of *Engineering*, a high authority, conceded that the impulse steam engine had attained the same efficiency as a compound piston engine.

Able engineers all over Europe have this problem in hand now, and if, as Mr. Brown writes, steam consumption has been reduced to 6.5 kilograms, or 14.5 pounds per horse-power per hour, the thermal problem is done, that is, the efficiency has overtaken the pressure engine, and now remains a development of various constructive problems that are almost sure to be rapidly worked out.

The speed of impulse engines follows the same law that applies to all motors driven by the efflux of fluids, the residual velocity, or, as we may say, the residual "rest," because there should be no velocity in the spent steam, is a resultant of two components, the movement of the fluid and that of the motor, the former being reversed in its course, and the relative speeds of the steam and the vanes or buckets being as 100 to 55. This rule produced in the first engines of De Laval and Parsons from 20,000 to 30,000 revolutions per minute. Five years of constructive effort has reduced these enormous velocities of rotation to one-third as much, and to a point where direct connection to the armatures of electrical dynamos is possible, and the required gearing of transmission is brought well within the resources of modern practice.

The conditions of operation in pressure or piston engines have been in part pointed out, and, as said, disclose the incentives that have led to the impulse method. Ultimate efficiency is not the object. This

cannot in the nature of things vary much between pressure and impulse. The force of efflux in fluids is equal to their gravity multiplied into their velocity, less the friction of orifices, and apparatus that will utilize the impinging force in the same degree that pressure is utilized by pistons will be equally efficient, other things being equal, so the objects to be attained by the impulse method for steam engines lies in another direction.

It will be revolutionary to institute complete comparison, and unfair in the present state of the impulse method, only ten years old, dating from the De Laval experiments. Steam consumption has fallen from 48 pounds to 14.5 pounds in that time, and from being a curious experiment the impulse engine has thrust itself in among its venerable competitors, not in obscure corners, but in high places. The electrical generators on the two greatest trans-Atlantic steamers are driven by impulse engines, supplied by Mr. Parsons about four years ago. There are many other cases that cannot be called to mind at this time.*

Other inventions of equal extent rise in these times, pass into the industrial field and soon disappear in the whirl of progress and change, that characterizes our age and time, but here is one of different nature and portent.

The application of motive fluids by impulse instead of direct pressure, that came about almost insensibly in water, means a wide revolution in steam, one that will not only modify constructively and economically nearly all that pertains to steam power, but will widen the field of application to hundreds of purposes, not now thought of.

Mr. Brown informs me that he is considering the application of impulse engines to traction purposes, but has naturally met with the impediment of variable speed, almost the only fundamental virtue inherent in the piston engine, and, as before said, confined mainly to this very case, so that he has attacked the exaggerated end of the problem, and will most likely abandon the scheme.

One other feature of impulse engines remains to be noticed. Expansion to the fullest degree must be a characteristic of any economical steam engine. This Mr. Parsons provided for at first in nine stages, and to transfer from one stage to the next involved a principal feature of objection to pressure engines, that of maintaining steam-tight running joints, not actual contact between surfaces in this case, but joints of such precision that while not in contact, no considerable leak could pass through them.

* During the first three months of this year, Mr. Parsons received orders aggregating 12,000 horse-power of his impulse engines. He has been compelled to call in the aid of other works, and at last accounts was operating his own night and day.—J. R.

This calls for an accuracy of work that cannot be attained with ordinary implements and by ordinary skill, but the De Laval engine avoids all this by a single application of the steam, first expanding it to the pressure of the atmosphere, and converting the expansive force into velocity.

This is, in my opinion, the keynote to the whole system, because engines thus made require no close running joints, and are simple in all their elements, down to the reducing gearing, and this, as now constructed, seems to operate without difficulty.

For eight years I have urged on all possible occasions the attention of engineers on this Coast to impulse steam engines, and their importance for special, if not general purposes. These propositions have been treated, like perhaps the present paper may be, as a visionary matter, but, however this may turn out, I am getting into very respectable company, and feel encouraged accordingly, hoping even to see at some future time an engine of 100 horse-power, wheeled on a hand barrow, a quiet, undemonstrative little machine that can be set in some corner out of the way on a common floor; also to see power distributed by impulse air engines over wide districts without much loss in transmission, without heat, danger, or the complication of electrical apparatus even.

This is, perhaps, enough for one occasion, all that it is safe to say, but having the floor I may as well go on and shock the engineering proprietaries with the second preposition relating to impulse, laid down at the beginning. It was as follows:

"The impulsion of fluids, elastic and non-elastic, will in future be performed by impulse derived from the momentum of rotation."

This proposition, almost wholly new to me, comes in a rough pen sketch and some explanation by Mr. Brown, of what he calls the centrifugal pump of the late Emile Bourdon, an engineer whose name will be familiar to most of those present by reason of his other inventions relating to fluid action.

Fourteen years ago, when I undertook the construction of centrifugal pumps here in San Francisco, I was informed by people whose opinions were certainly to be considered, that pumps of that kind would not operate against heads exceeding forty feet, and they proved it too by rules, showing that an increase of resistances with head, fixed a commercial, if not practicable, limit at that pressure. Combining two pumps I found their force in series was multiplied accordingly, and a pump to operate against a head of eighty feet was made and operated successfully.

Single pumps have since then been made to raise water 160 feet without encountering the theoretical resistances commonly set forth in

authorities, and I have the boldness to believe that the theories applied to these pumps are wrong, and that what we call the centrifugal method of pumping has no such limits as have been fixed by computation. I presented in a previous paper before this Society the enormous increase of capacity, and a corresponding decrease in cost, of continuous flow pumps, and came near some predictions that if the paper were to be written now would form a portion of it.

Heretofore we have operated in one line of construction, or method, for generating what we call centrifugal force, or a force derived by rotation for impelling fluids, but if instead of centrifugal force we consider the momentum of revolution, and deliver this momentum impulsively to the performance of work, we are carried into a new field, and the limitations of centrifugal pumping will disappear, theoretically at least.

If a body of water is set in revolution by being dragged over large frictional areas by an impeller whose velocity at different radii cannot conform to that of the water, we cannot expect to impart to the water a very large proportion of the original energy, or driving power, employed to set the water in motion; but if the water is gradually set in rotation, almost without friction or retarding influence, except its inertia, that water applied impulsively should give out again in useful effect within a few per cent. of the original energy or power. To do this the water should not be whirled around in a stationary vessel or case, but in one revolving at the rate desired for the water to attain, and the impulsive effect taken off, so to speak, by impingement on the fluid to be raised or impelled.

It is, perhaps, inexpedient and unfair to bring to the Society's notice a matter so little supported by tangible data at this time, but knowing that some of our members are now engaged in hydraulic problems, relating to the impulsion of fluids without the losses of intermittent motion, and as the Bourdon pump is an impulse machine, it cannot be passed by. The proposition involves both the generation and application of the pumping or impelling force, and there is, of course, no direct analogy to steam engines and water-wheels that draw from an accumulated store of energy.

The Bourdon scheme involves a translation, it may be called, of the energy as well as its application by impulsive effect.

Suppose that a cylindrical vessel like a centrifugal drying machine, having inward projecting vanes around its interior periphery, is filled with water, and set in revolution up to a velocity of 80 feet per second at the interior tips of the vanes. The water would then be moving at a rate the same as that produced by a head of 100 feet, and if this water could be diverted tangentially, and directly applied to the propulsion of other water to be raised or impelled, the losses would be

inconsiderable. To take off this revolving water tangentially a discharge nozzle has to be introduced inside of the revolving chamber. This discharge pipe would, of course, obstruct or prevent rotation of the water in the zone occupied, creating a frictional area equal to the width of the revolving chamber multiplied by a circle touching the end of the discharge pipe. This frictional area is not more than a third what is encountered in a common centrifugal pump, and is that of viscosity principally.

This indicates in words the experiments being tried by Mr. Brown, who, as I understand, proposes velocities far beyond precedent, or possible, with a common centrifugal pump. The same method can be applied to air or any other elastic fluid the same as water.

There may be present members who are familiar with the experiments and views of M. Bourdon. I will not pursue the matter further now, but with consent may at some future time lay before the Society some results of experiments now going on that may modify present views of the impulse method of translating energy.

DISCUSSION.

MR. A. M. HUNT.—A brief description was given of a turbine steam motor invented by R. H. Hewson, of San Francisco, a number of which have been manufactured and tried.

The design of this motor is crude, and its economy not good, but there is no reason why, by a proper proportioning of the parts, an engine of good efficiency may not be made of it.

A patent lately issued to Mr. Hewson embodies the idea of multiple expansion of the steam through a series of buckets, in this way following the lines on which Parsons has been working.

ENGINEERING EDUCATION.

BY PROF. L. S. RANDOLPH, MEMBER OF THE ASSOCIATION OF ENGINEERS
OF VIRGINIA.

[Read April 17, 1895.*]

THE analogy between the college or the university on the one hand and the manufacturing establishment on the other, is far more complete than is usually supposed.

The verdant freshman represents the raw material, the different undergraduate classmen the material in process of construction, and the graduate with his diploma the finished product.

As it is necessary that the manufacturer should carefully study the market in order to know the kind and quality of goods which the public and the exigencies of life demand, the method of manufacturing, that the most economical results may be obtained, and the raw material, that the best and most suitable only may be taken; so it is necessary that the educator should study the conditions of life to see what is required of the student; in what points he must be prepared, and with what degree of finish, the method of teaching, that the best results may be obtained, and the standard of admission, that he may obtain the desired quality of raw material.

The purpose of this paper is to discuss what knowledge will best fit the young graduate for the practice of his profession and what will best enable him to attain that *permanent* success in his profession which is the true end to be aimed at and which alone will repay him for the work of preparation and for the weary years of waiting and trial when his ability is being proven; and we will also discuss some of the methods which may be used to impart this knowledge.

Webster defines engineering as "the science and the art of utilizing the forces and materials of nature," and the engineer as a person skilled in the principles and practice of engineering, or one who carries through an enterprise by skillful or artful contrivance; an efficient promoter—a manager.

We see running through these definitions the idea of a manager or superintendent and not only the one who knows how; the idea of an executive officer, not only a consulting or directing officer.

The definition which seems to the writer to best fit the case is "one who applies the discoveries of the scientist to the needs of mankind," and we find this similar to a definition which can be readily gotten from

* Manuscript received June 7, 1895.—*Secretary, Ass'n of Eng. Soc.*

Webster's definitions: that is, one skilled in utilizing the materials and forces of nature.

From a recent catalogue of one of our most prominent schools of engineering we find the following disposition of its graduates:

Chief engineers of railroads, consulting and inspecting engineers,	} 45 per cent.
assistant engineers of railroads, city engineers	
Managers, superintendents, presidents and contractors	29 "
Engineering instructors	6 "
Other professions and indefinite positions	20 "

We find from the accepted definitions and statistics that we get the idea not only of the necessity for a thorough knowledge on the part of an engineer of scientific laws and natural phenomena, but of the best way also to apply them for the use and benefit of mankind.

The engineer must be not only thoroughly acquainted with the scientific facts, but he must have sufficient knowledge of economic principles and the ordinary facts of every-day life to apply them to the best advantage. How many of us, yielding to the fascination of scientific study and research, have awakened just in time to find that the scientist was strangling the engineer.

The time comes when the engineer must do the work which properly belongs to the scientist, and then, swinging to the opposite side of his orbit, do the work of the clerk or accountant.

The young man, thrown out on the world, can no more choose his pathway, as a rule, than the wreck on the wide ocean; but so long as he is able to hold to the profession of engineering, he should be prepared to take whatever work comes in his way, and in whatever part of the field of engineering it may lie.

Let us see what will be required of the engineering student.

We find the field of the discoveries of the scientist with which the engineer has most to do to be physics, chemistry, mathematics and astronomy. In physics—mechanics, heat, light, sound, electricity and magnetism.

Under the head of mechanics we have statics and dynamics of solids and liquids, and kinematics.

Under the head of heat we have conduction, radiation and reflection and the effect of heat in producing expansion.

Under the head of light we have refraction, defraction, reflection and the composition of light colors and polarization.

Acoustics—propagation of sound waves, its reflection and the interference of sound waves.

Electricity and magnetism—the relation between electromotive force, current and resistance, induction and magnetization.

Chemistry—the composition of bodies and the theory of their

reaction, both for organic and inorganic compounds; and under this head should be included the closely allied sciences of geology, mineralogy and metallurgy.

Mathematics, while only a tool, is so indispensable an implement that little could be done without it.

Astronomy we find of comparatively little use to the majority of engineers.

Under the above subjects we will find nearly all the fields for scientific investigation; and it is in these fields that the discoveries are made which it is the engineer's province to apply or make use of.

In the early days of engineering education it was deemed sufficient that the engineer should be thoroughly grounded in the above, that is, he should understand the scientific side of the question only. As the subject of engineering education was developed, three different schools were evolved: The German or Continental, the English and American.

In the German or Continental the theoretical side of the question was given the greatest prominence and the student was thoroughly drilled in this side of the question rather to the exclusion of the other.

In England the opposite system was developed and the student was given a practical problem and drilled in that; his work leading him back to the scientific principles involved.

In the United States the system of instruction which has been developed may be said to be a combination of these two systems, a mean between the two extremes. The student is thoroughly grounded in the elements of mathematics, physics, astronomy, and chemistry, and from this he is lead to their application to engineering problems, especial attention being paid to those subjects which are of greatest importance in the particular branch which he wishes to follow, whether civil, mechanical, mining, military or electrical, and the examples used for applying these principles are drawn from practice in the particular branch under study.

That this system of giving the student instruction, in the method of applying the facts which he had learned, was a long step in the right direction, will, I am sure, not be questioned, in the face of the marked success of the technical schools in this country. But the detail of this work; what to leave out and what to put in and how far certain subjects should be carried in the different divisions is a matter which has been much debated, is being debated, and will probably be for many years to come. Probably no two men could be found who would agree, or whose practice would harmonize, each one working toward that goal which he thinks will bring greatest benefit to his pupil and reflect the greatest credit on himself.

All of our colleges are limited to a certain given time, usually four

years, within which the student must be taken with a certain amount of knowledge and brought up to such a state of knowledge as will enable him to reach the standard demanded by his degree, and the problem is to use this time to the greatest advantage possible as an illustration:—

Should the theory of arches, bridges and foundations be taught to the mechanical, electrical and mining engineer, and if so, how far should it be carried and to what extent should its application be taught? That the civil engineering student should be carried further goes without saying; but how much further? In some colleges the courses in this particular are almost identically the same. In others, all but the civil stop with the theory of the subject. The writer's experience has lead him to believe that the latter is the correct practice.

Again, should the civil engineering student be taught thermo-dynamics, and its applications to the steam, air and gas engines and to refrigerators? All these are absolutely essential to the mechanical engineer. The theory of thermo-dynamics should, of course, be taught, but should its applications also be taught to the civil or mining engineering student? In the writer's own experience several cases have arisen where civil engineers have had pressing need of a knowledge of refrigerating processes, but it would seem that the percentage of such cases is not great enough to warrant requiring each student to go over all of this work to the exclusion of other work in the line of his specialty.

The question of chemistry frequently comes up for the mining or metallurgical engineer. A thorough knowledge of inorganic chemistry is absolutely essential; but for the civil, mechanical or electrical, how much and to what extent should it be carried? Should these last two have organic chemistry and any work in biology? Should either one take up water supply or sewage work?—such knowledge would be extremely valuable and can scarcely be dispensed with; but with this important exception, the engineer, it may be said, does not have sufficient use for these subjects to pay him for spending the time over it.

Should the mechanical engineer alone, as having to do with the design of machinery, be taught the principles of machine design? It is almost universally acknowledged that the application of the discoveries in the field of electricity were held back for years by ignorance of the subject on the part of those who designed the first electrical machinery. So that we can say that for the electrical specialist, as well as for the mechanical, it is absolutely essential; but does the civil or mining engineer have use for this particular knowledge? Some rather amusing designs would indicate that they do not all get it.

It is freely acknowledged that the theory of the subjects given above should be carefully brought out; but to what extent should their application be taught, and from what source should the problems illustrating

their application be selected? It is here that the differentiation starts between the branches of engineering education, and it is after this that the principal difficulties of the problem present themselves.

As has been said before, it will scarcely be denied that the plan of teaching the application of theoretical and natural laws, and the drawing of deductions from observations upon them, was a great step in advance, but is there not another step which can be made? Having made the application to a given definite problem, should we not also bring out and determine the principles which govern the value of the problem when solved?

Having studied and observed the action of the discovered natural laws, and having applied the information so obtained to the solution of problems, should we not also carry the student to such a point as to enable him to determine what problems are worth solving and what their value will be in dollars and cents when solved? For the world measures the efficiency of the engineer in dollars and cents.

WOODEN BRIDGE CONSTRUCTION ON THE BOSTON AND MAINE RAILROAD.

BY J. PARKER SNOW, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read May 15, 1895.*]

THE subject of iron and steel bridges has been quite extensively written up in our technical literature during recent years, but wooden bridges are seldom discussed, and when mentioned, are generally treated as temporary structures or excuses offered for their use. The building of such bridges is, however, a live business on the Boston and Maine Railroad, although the impression seems to be prevalent in many quarters that such construction is obsolete and out of fashion.

This paper is offered to describe the present practice in wooden bridge construction on the above-named railroad, and if not considered as in line with present approved practice elsewhere, may at least have some interest as a history of one branch of the bridge-building art.

On the system operated by the Boston and Maine there are 1,085 wooden bridges of all kinds in a total of 1,561. This number covers overhead as well as track bridges and includes everything of 6 feet clear opening and upwards, except stone box culverts. The proportion of wooden bridges grows less each year, although more than half of the new structures built to replace old bridges are built of wood.

The types most commonly used for new work are pile trestles, plain stringer bridges, compound stringers made of timbers keyed together to get greater depth than is possible with single sticks, pony trusses of the Queen post and Howe type, and Town lattice bridges. At the present prices of iron bridges Howe trusses of considerable span, if built in first-class shape of Southern pine timber, cost almost exactly the same as iron ones and consequently are practically ruled out. A considerable number of stringers trussed with rods beneath are in existence, but are seldom built at the present time.

Spruce timber is used for all parts of Town lattice bridges, and for caps, stringers and ties in many trestles and plain stringer bridges on Northern lines. On lines south of Central New Hampshire, however, Southern pine is almost invariably used. Spruce is sufficiently durable when roofed in, and on account of its lightness is much better than Southern pine for lattice trusses, but its softness and tendency to warp and the difficulty in getting sticks of sufficient length make it unsuited for Howe truss work of magnitude. For bottom chords of lattice bridges of over 100 feet span, recourse must be had to Southern pine also on

* Manuscript received June 4, 1895.—*Secretary, Ass'n of Eng. Socs.*

account of the difficulty in getting spruce of the requisite length. Tamarack, oak and chestnut are used for piles in trestles.

The life of sawed spruce exposed to the weather is but about six or seven years. Southern long-leaf pine of prime quality in similar conditions is reliable for twelve to fourteen years. When covered in and well ventilated and kept free from accumulations of dirt, either timber will last forty to fifty years. Sawed chestnut for ties, stringers, etc., is about intermediate in durability between spruce and hard pine. It has been used for bridge timber on the Southern lines of the system considerably in years past, but is not so used now and is not recommended.

Tamarack piles in dry land trestles will last eight to ten years, chestnut and oak of good quality fifteen to twenty.

The loads used in calculating new wooden bridges are somewhat lighter than the standard used for those of iron. It is thought that wooden bridges are necessarily of a less permanent character than iron ones and that within their natural life the weight of rolling stock will not increase so much above what it is at present as may occur in the life of an iron bridge; again, if wooden bridges are found to be too light for future loads, they can be strengthened, or supported on trestle bents much better than iron ones, and a wooden bridge, like a piece of masonry, will give abundant notice of distress before it will fail entirely. The governing reason for building wooden bridges instead of iron ones altogether is, of course, their less first cost, and if the full standard load for iron bridges was used in designing them this element of advantage would be reduced and they would be no more serviceable or satisfactory for present use than if designed for the lighter load. The load used is a train of consolidation engines weighing, each, with tender, 172,000 pounds, with 24,000 pounds on each driving axle, or 80,000 pounds on two axles, seven feet apart. This is somewhat in excess of engines in use at present on this system, and although considerably lighter than the load used in designing iron bridges, the considerations given above seem sufficient to justify its use.

The usual unit strains used are, for Southern pine 1,000 pounds per square inch direct tension and 800 compression; the latter, of course, reduced for ratio of length to diameter. For spruce this unit is taken at 650 compression and 800 tension. For fiber strain in stringers and beams the unit is 1,200 pounds per square inch for both hard pine and spruce. The reason for adopting this figure for spruce is that in exposed situations, as is the case with stringers, the life of spruce is so short that it is a waste of material to provide for the much talked about increase in engine loads, and while sound, this unit gives a very satisfactory bridge. For combined transverse and longitudinal strain two-thirds of the former is added to the latter and 800 pounds used as the unit. Longitudinal shear-

ing is kept below 80 pounds per inch and transverse crushing on hard pine from 350 to 400 pounds per square inch, depending on whether the whole width of the stick is covered or only a small area.

These unit strains are used for new work; an old bridge will, however, stand up and carry its load when the computed strains in some parts are very high. Of the three classes of bridges built twenty years ago, iron pin, iron riveted and wooden, all of which figure equally near the danger limit, common prudence will select the pin bridge as the first one to be removed, the riveted one next and the wooden one, if sound, last.

The cost of bridges for single track of 120 feet span will compare something as follows:—Iron \$5,300. Howe truss of Southern pine and iron angle blocks \$5,000, and spruce lattice \$3,500. Below this span, the advantage of wooden bridges over iron ones in point of cost will increase and above it the advantage rapidly reduces to nothing.

The standard spacing of bents in pile trestle bridges is 15 feet. Solid caps drift-bolted to the piles and girder caps with riders are used indiscriminately, the former being the cheaper and the latter making the most rigid structure. The stringers used on these trestles are for single track, two 8" x 16" under each rail and one of the same dimensions on each side placed 10 feet apart from outside to outside. The stringer sticks are 30 feet long, laid to break joints; the two sticks under each rail are spaced 2" apart by cast iron spool separators and $\frac{3}{4}$ " bolts, four at each cap. The stringers are secured to the caps by drift bolts. The floor consists of ties 6" x 8" x 12 feet long, laid 4" apart in the clear. Tie spacers 6" x 8" are placed flat on the ends of these, notched down one inch and bolted to every fourth tie. These bolts have a round burr washer under the head on top and a Warren nutlock for washer at the lower end. The floor is kept in line by occasional lining spikes or drift bolts through the ties into the side stringer.

The tie floor above described is standard for all wooden bridges; it is shown in cross-section Fig. 1. In designing, the ties are considered as

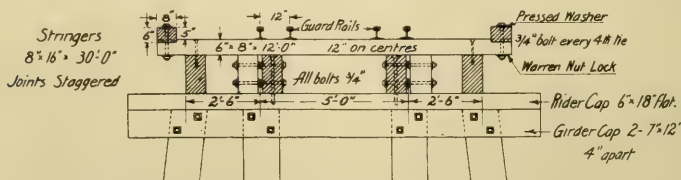


FIG. 1. STANDARD TRESTLE; 15 FT. BENT.

distributing the load so that 80 per cent. is carried by the main stringers and 20 per cent. by the side ones. The continuity of the stringer sticks over two spans is considered as reducing the moment of the load at the centre of span by 10 to 12 per cent.

Plain stringer bridges are built the same as above described for trestles, except as the stringers do not have the advantage of continuity over supports, the sections must be larger for similar spans. The depths of the sticks should not be less than $\frac{1}{12}$ to $\frac{1}{14}$ the span.

When the span becomes too great for merchantable depths of timber, or convenient thicknesses, recourse is had to keyed stringers. These are made by placing one stick on top of another and framing cast-iron keys between them, as shown in Fig. 2. A vertical bolt at each key prevents the timbers from separating.

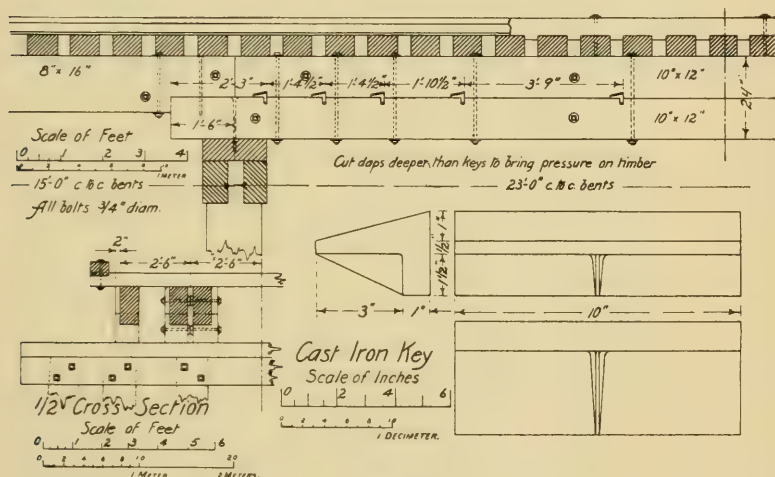


FIG. 2.

These keys are proportioned for the longitudinal shear, and hence the total depth of the compound stick can be used in computing its moment of resistance. The keys are cut $1\frac{1}{2}$ " into each upper and lower stick, and an attempt is made to distribute them according to the intensity of the shearing strain; but near the ends of the stringer a strict adherence to this requirement would bring them so near together in some cases that the daps might split out. With notches $1\frac{1}{2}$ " deep, it is desirable that they should be at least 18" apart. The quantity of longitudinal shear at the neutral axis, between any point and the end of a beam, is a function of the fiber strain at that point; being equal to $\frac{b.d.f.}{4}$ when b . is the breadth, d . the depth and f . the extreme fiber strain.

A convenient way to locate the position of the keys is to draw a line the ordinates of which represent the moment of the load and lay off to some convenient scale, $\frac{b.d.f.}{4}$ as an inclined ordinate at the center of this curve. Now, beginning at the base, space off on this inclined line the value

of each key, and draw horizontals through the points of division; these horizontals will cut the moment curve into spaces showing the proper field for each key. The friction between the two sticks, induced by the load and by the grip of the vertical bolts, helps to resist the longitudinal shear, and a proper proportion can be added to the value of the key when spacing off the inclined ordinate.

These stringers require considerably more material than trusses of equal strength, but the labor on them is small and they can be put in place and prepared for the passage of trains in much less time than trusses. This latter quality is of great importance, and should be given more attention by bridge designers than it generally receives. This style of bridge works in with the ordinary trestle spans very conveniently when it is desired to make a wide opening for a runway for ice or logs, or for a highway underpass. The lower stick of the compound stringer is extended beyond the upper one to furnish a seat for the regular stringers of adjacent bents. In cases, too, where the trestle bents are high and expensive it will lessen the cost of the structure to make alternate spans compound or keyed stringers. This style of bridge is available up to clear spans of 30 feet.

Pony trusses are used for spans between 30 and 60 feet, generally of the Howe type. For overhead highway bridges requiring trusses modified pony Howe trusses are used almost exclusively. For these latter and for track bridges it is altogether better to use floor beams, distributed along the chord about $2\frac{1}{2}$ feet apart, rather than to concentrate the load at panel points by means of stringers carrying the load to large floor beams, as is done in iron bridges, and it is generally best to hang the floor beams below the chord. If the plank floor of highway bridges is laid directly on these cross floor beams it brings the plank parallel to the line of travel; this is considered objectionable, and hence longitudinal spiking joist or stringers, 4 to 6 inches thick, are laid on the cross floor beams and the plank spiked to these. On bridges carrying light traffic a single 3" floor is used, but where the travel is heavy it is economical to use a double floor, generally 2" below and 3" for wearing surface. The under plank lengthens the life of the floor very considerably by keeping it safe for a long time after the corners of the upper plank have worn through.

Railroad bridges of this class should always have the top chords stayed against side motion, as shown in Fig. 3, and it pays to protect the trusses from the weather by sheathing and roofing them in.

For spans greater than is desirable for pony trusses the Town lattice built mostly of spruce is our only resource. As before stated, Howe trusses of Southern pine cost almost as much as iron bridges at present prices. Spruce, the only available timber growing in the region in

which these bridges are used, is not well adapted to Howe truss work, but is excellent for lattice bridges. This style of bridge seems never to have been developed to much extent outside of New England, and it is fre-

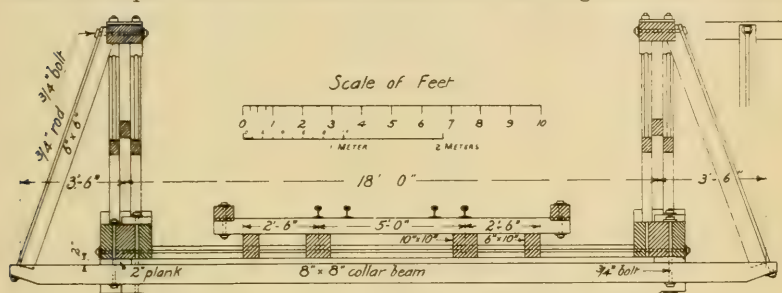


FIG. 3. SWAY BRACING FOR PONY TRUSSES.

quently referred to as peculiarly unscientific and wasteful of timber. It is, however, the best of the purely wooden bridges, and its present survival here and its economy over all other types disproves its wastefulness. These trusses should always be built double, that is, with two webs like a box girder. Single web trusses can be made strong enough up to 80 feet span, but they do not stand so steadily or keep in line so well as those with double webs. The distance between the webs is immaterial, but is generally made equal to the thickness of two chord plank, from 6 to 8 inches. Outside of the webs, it is not deemed advisable to use more than three thicknesses of plank on each side; this confines the chord to 8 planks, and as this is generally not sufficient to give the requisite strength, a second chord is added at the second web intersection. These second chords serve not only to carry chord strain, but also to stiffen the diagonals and to assist the outer chords to distribute the shear between the tension and compression members of the web.

The chord strength of these trusses is computed by assuming the distance between the centers of outer chords as the effective strain depth of the truss, and reducing the section of the inner chords in the ratio of the squares of their distances from the neutral axis. In the case shown on the inset this ratio would be nine-sixteenths. In several bridges of this type now standing on the Boston and Maine road, built in former years, there are three sets of chords, but the third chord has but little theoretical value, and judging by the amount that the joints are pulled they assist but little in carrying the chord strain. The proper arrangement of the breaks in the planks of the lower chord affects the strength of the whole much the same as the arrangement of eyebars affects the strength of pins in an iron bridge.

In bridges of 125 feet span and upwards it becomes necessary to fasten the abutting ends of the chord plank together and the device

shown on the inset is used for this purpose. The gib-bars are wrought iron, varying in section with the thickness and width of plank to be joined; hexagon nuts are used on the yoke rods so as to necessitate as little cutting of the chord stick as possible. A ribbon is sometimes put between the webs at the middle height of the truss, as shown in the inset, with the idea of stiffening the web and preventing vibration.

DISCUSSION.

MR. B. W. GUPPY.—The Town lattice truss was patented in 1820 or 1821. The inventor, Mr. Ithiel Town, published pamphlets in 1821 and 1831, describing the bridge, and the claims that he makes therein as to the economy and durability of this type of bridge have been fully substantiated. Copies of these pamphlets are in the possession of the Boston Public Library.

Some of the advantages that Mr. Town claimed for his bridge are as follows:

“Suitable timber can be easily procured and sawed at common mills, as it requires no large or long timber.

“Defects in timber may be discovered and wet and dry rot prevented much more easily than could be in large timber.

“There is no iron-work required, which at best is not safe, especially in frosty weather.”

This last statement is rather amusing, as Mr. Town previously states that the trusses can be built either of wood or iron. Moreover, it is due to a free use of iron that the present development of the bridge has been obtained.

Iron is used principally in the form of bolts and rods, and its use increases the strength of certain parts like the tension chord, and allows of adjustments to take up the shrinkage of the timber.

Wedges at the ends of the pins or treenails were used to keep the sticks in close contact. Bolts at the intersections of chords and lattice are now used for the same purpose, and they also add to the strength of the chord connections.

Iron chord couplings add a large percentage to the strength of the tension chord.

A Howe truss system of lateral bracing is used instead of the Burr system originally adopted, and by means of turnbuckles on the rods placed so as to be easy of access, adjustments can be made to keep the trusses properly in line.

Formerly the floor beams in through bridges rested on top of the bottom chord, bringing most of the load on the inside chord sticks and web

system. The present practice is to hang the floor beams below the bottom chord by hanger bolts alternately on opposite sides of the chord, as shown on the drawing accompanying Mr. Snow's paper. This distributes the load equally between the two web systems and adds an amount to the headroom equal to the depth of the chord plus the depth of the floor beam.

Some of these bridges have a very long life. One that was taken down on the Boston and Maine system last year and replaced by a similar structure was claimed to be over fifty years old, although no exact record could be found. This refers to the trusses. The floor was newer, having been renewed and strengthened. The timber was in fairly good condition, extreme lightness of construction being the principal cause for renewal.

Another bridge taken down the year before was over forty-five years old.

In use these bridges stand a great deal of abuse. A butting collision on the approach to one bridge piled the cars of one train up through the roof. Beyond breaking a hole in the roof, and cutting up a few ties, no damage was done to the bridge. Another collision in which only one train participated, the bridge acting as a buffer, resulted in considerable damage to the end vertical and web; but the bridge is still in use without any repairs and is considered to be perfectly safe. In another case logs at high water broke off the ends of the lattice. Bolts were put in connecting the floor beams with the upper lower chord, relieving the lower joints of all vertical load, and as they are still strong enough to transmit the chord stress, the bridge is used without any apprehension of danger. This bridge has the floor beams resting on top of the bottom chord. If they had been hung below they would have protected the ends of the lattice.

During the recent floods in New Hampshire, a pier was washed out from under a two-span bridge. As the invariable practice is to make these bridges continuous over all intermediate supports, the bridge was saved.

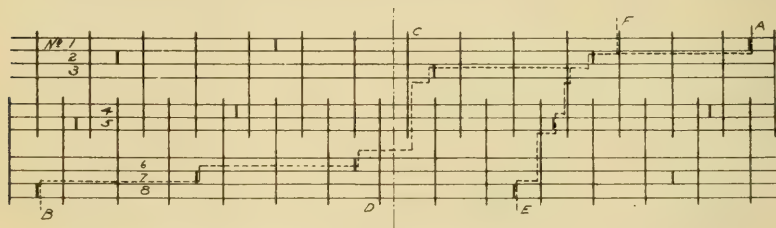
At the same time the abutment was washed out under the end of another bridge, causing one of the trusses to settle several feet. It was blocked up into place and is now in use, the flexibility of the construction preventing any serious damage.

Fire is the principal enemy of these bridges, but the danger has become much less since the introduction of coal burning engines. The fires usually start in the roof and are generally extinguished before they do any damage to the trusses. A good coat of white-wash together with water barrels, buckets and a ladder at each bridge are the means of protection.

The road has these bridges insured, but as fatal fires are so few, and the losses are generally so small, it would seem to be economy to have the road do its own insuring.

In designing this truss, the practice is to use a panel length of from four feet to four feet six inches, the panel length being the distance between the chord pinnings for one of the lattice systems. The pinnings of the second lattice system are half way between those of the first. This brings the distance between two pinnings equal to one half a panel length. The panel length is taken at such a length within the limits given as will bring the total number of panels equal to $n + \frac{1}{2}$ where n is any integer. This arrangement brings the center line of truss half-way between two pinnings, making the chord stick cuts symmetrical, and making the odd length sticks the same at both ends.

The method of arranging the cuts in an eight-chord stick is shown in the accompanying diagram.



In figuring the strength of the tension chord, the following assumptions are made:

(1) When there are four pins and one bolt at a pinning, the net area of the stick is taken as the depth in inches minus five, multiplied by the width.

(2) The value of a pinning to transmit stress between two sticks is taken as 1,100 pounds for each pin and 600 pounds for one bolt, making a total of 5,000 pounds for one pinning of four pins and one bolt.

These values were arrived at by figuring the pin for bearing, shearing and bending; the limiting value being given by the strength of the pin to resist bending. The lever arm was taken a constant of 1.3 inches for the three thicknesses of plank generally used, namely $2\frac{1}{2}$, $3\frac{1}{2}$, $3\frac{3}{4}$, as the flexibility of the pin must cause the load to be concentrated near the inner edge of the stick and the examination of pins taken from old bridges seems to justify this assumption.

When wrought iron chord couplings are used, the strength of a coupling is the net value of four $\frac{7}{8}$ -inch rods at 10,000 pounds per square inch, or 16,920 pounds.

When chord couplings are used, there are two cases to consider: (1) when the strength of one coupling plus three pinnings is less than the net strength of the stick, and (2), when it is greater.

In the second case, the weakest center section is practically straight across the chord on the line CD . In the first case, the minimum value of chord is along the line AB . There is also a section EF , $1\frac{3}{4}$ panels from the center, the strength of which should be investigated, as in some cases it has a less value than the center section.

In the bridge shown in the drawing, the bottom chord is composed of six $14 \times 3\frac{7}{8}$ -inch sticks and two 14-inch $\times 2\frac{7}{8}$ sticks. Net value of one $14 \times 3\frac{7}{8} = 9 \times 3\frac{7}{8} \times 1000 = 34,875$ pounds.

One coupling = 16,920 pounds,

Three pinnings = 15,000 "

31,920 " which is less than net stick and
the minimum center section will be along the line AB .

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	3 "	31,920
" 3	1 "		16,920
" 4	net stick	$14 \times 2\frac{7}{8}$	25,875
" 5	"	"	25,875
" 6	1 coupling	1 pinning	21,920
" 7	1 "	3 pinnings	31,920
" 8	1 "	3 "	31,920

218,270 lbs. net value of
center section.

Section $1\frac{3}{4}$ panels from center

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	1 pinning	21,920
" 3	net stick	$14 \times 3\frac{7}{8}$	34,875
" 4	"	$14 \times 2\frac{7}{8}$	25,875
" 5	1 pinning		5,000
" 6	net stick		34,875
" 7	net stick		34,875
" 8	1 coupling		16,920

206,260 lbs. net strength
of chord $1\frac{3}{4}$ pan-
els from center.

With sticks 16 inches deep and the same widths the center section will have a value of 229,770 pounds, and the other section 235,260 pounds, being the greater in this case. Inspection shows that the strength of the center section is increased only by the increase in sticks 4 and 5.

This span is about the limit of this style of bridge without the use of an arch, although spans have been built up to 150 feet.

The shear is assumed to be uniformly distributed over all the web planks cut in a given section. The members are so thoroughly pinned

together that they cannot possibly act as single independent systems to be separately calculated as is advocated in some text-books, but the strain must be equalized throughout a vertical section much as would be the case with a solid web.

A lattice truss should extend well on to the masonry. For reasons connected with the proper construction of the floor this extension on the abutment should be about one and one-half panels; a solid bolster should be placed under the chord for this distance and under this should be the cross wall blocking. The compression diagonals near the end of the truss deliver their shear to very short tension members; the fastenings of these do not seem to be able to carry the load delivered to them, and the bolster is needed to help take the thrust of the compression members direct. Many old bridges built probably without much knowledge where the maximum shear occurs have failed by having the bottom chord split down or literally sheared at the edge of the wall plate by this action. Proper bolsters would have largely prevented this. It is the custom now to put solid posts between the webs at the end and second panel points extending the whole depth of the truss. These cut through the two middle plank of the chords and would endanger shearing the bottom chord if the bolster did not extend beyond the cut-off. These solid posts furnish a substantial support to pin the short ties to and to receive the compression members which do not reach the bottom chord. None of the trusses built in this way have shown indications of weakness in the way explained above. The panels should be between 4 feet and $4\frac{1}{2}$ feet and the web plank should be given inclinations of nearly 60° with the horizontal.

The pins used in these bridges are 2" oak. They should be of well seasoned timber, and should be carefully turned so as to drive tightly when the bridge is erected. Much depends on the pins. In old and weak bridges the pins are frequently found much distorted. In heavy trusses all plank must be at least 12" wide in order to take four pins at the chord intersections. At the web crosses two only are used. At all chord intersections and some in the web a $\frac{3}{4}$ bolt is used to hold the plank firmly together. This bolt is deemed of great importance from its preventing the plank from opening, which would greatly increase the leverage on the pins. It is possible that iron pins perhaps of heavy pipe rather than solid bars would mark an advance over the present practice, but they have not yet been tried so far as the writer is aware.

The floor beams in these bridges are at present invariably hung below the chord, two beams per panel. The ends of the web plank projecting below the chord are cut into to allow space for each floor beam. They are hung by bolts passing through the open spaces in the chord and through washer blocks on top of same.

The lateral bracing is the Howe system, that for the lower chord being laid directly on top of the floor beams, and the stringers cut over it; 5" by 8" to 12" is the size generally used. The main stringers under the rail are 10" by 10" and the side stringers 6" by 10".

The load used for floor beams is 5,500 pounds per lineal foot of track, which is assumed to cover both the live and dead loads. Eighty per cent. of this is assumed to be on the main stringers and 20 per cent. on the side ones. The clear width in these bridges is 15 feet. This makes the effective length of floor beams 18 feet or more and calls for sticks so large that it is best to use Southern pine for them. Spruce can be readily obtained of sufficient size, but when so large and in so exposed a situation it twists and checks badly. Southern pine is used also for bottom chord plank for spans greater than 100 feet, and should always be used for bolsters and wall plates. The stone parapets of all through wooden bridges are brought in so as to be flush with the face of the abutment (see inset). This serves to protect the timber floor from the weather, obviates the large amount of blocking needed on the stonework when it is not so done, and shortens the bridge floor.

Lattice bridges are built on the Boston & Maine Railroad as above described up to 150 feet clear span. They are, however, rather unwieldy at this length and it is preferred for spans above 125 feet to build them with an arch inserted between the webs. These arches are built up to the required section with 2" or 3" plank and bolted to the trusses at every lattice cross which comes in contact with the arch. They abut against the stonework below the lower chord on large Southern pine skew-backs scribed to the stone. The skew-backs are mortised out in steps to receive the square ends of the planks. The planks of the arches are well spiked when laid and radial bolts are freely used to bind them well together. The load is brought upon the arch by vertical rods passing through the arch and down through the lower chords and floor beams.

The arch is proportioned to carry its own weight and the whole live load on the bridge. The trusses are made of the same section as those of one half the span which have no arch. These compound bridges are very satisfactory, being rigid under traffic and of more pleasing appearance than when built without arches. They are also much more economical of timber than simple trusses for the reason that the arch uses timber wholly in compression, in which condition the entire section is available; whereas when timber is called upon to act in tension a large portion of the section must be wasted in making the connection.

In order to secure a satisfactory track surface after several years' use, there must be considerable camber framed into lattice bridges. For trusses without arches, there should be 1" for each 25' of span and for those with arches 1" for about 37½' of span.

The lattice bridge has been described thus at length, partly because it has not been so fully treated as other styles in technical literature, and because it is the only kind that can be built in competition with iron at present prices. On the Boston & Maine system, there are many Howe and Pratt bridges, a few Burr, Briggs and Child's trusses and many of mongrel type; but the Town lattice has a large plurality over any other kind and there seems to be ample and good reasons for its natural survival.

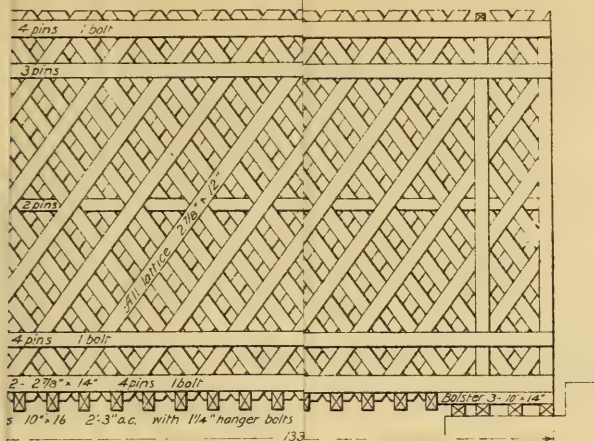
These bridges as built to-day are, in all their important details, direct descendants of, and very near kin to, those built in years past by the bridge carpenters of Northern and Central New England. Those built by David Hazelton and his men furnish the basis of the present practice on this road and although they were built without engineering advice, they bear analysis well, with the possible exception of the bottom chords.

It has come within the observation of the writer many times that when an intelligent master-carpenter has had the care for a term of years of a line of wooden bridges covering any given style of truss, he gradually brings their parts, when building new ones, to almost the exact size called for by scientific analysis when actual loads are used in calculation. He will use iron rods that are too small for they show him no distress unless they break, but the timber parts guide him to right results.

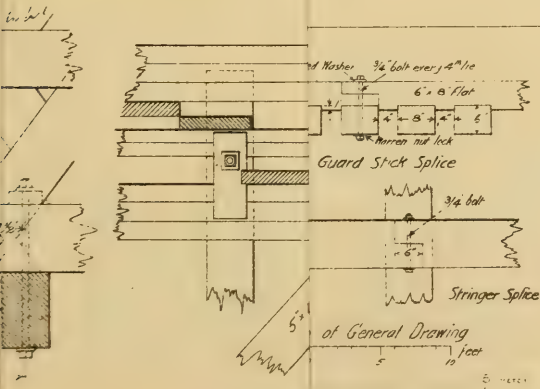
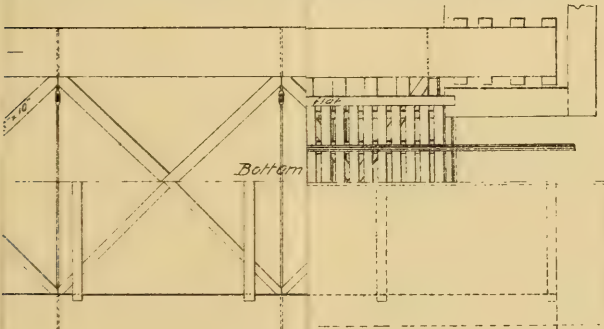
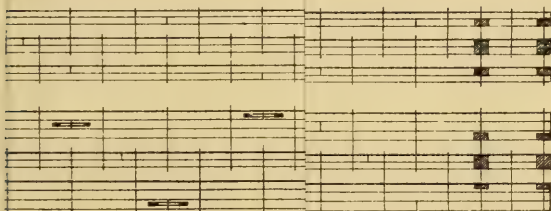
It is this property of a timber bridge, its certainty of giving warning of approaching weakness, that has kept the record of wooden truss bridges so clear from fatal disasters. It is not reasonably safe to use a light iron bridge until it is worn out, but a wooden one may be used till its deterioration is rapidly approaching the end. Neither is it safe to entrust light iron bridges wholly to the care of workmen not technically educated; the timber parts of wooden ones may be.

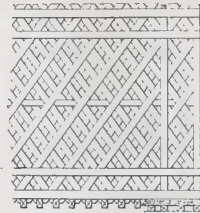
It is no part of the intention of this paper to advocate building wooden bridges instead of properly designed iron ones, but rather to describe the favorite styles now used on those parts of the Boston & Maine Railroad where wooden bridges prevail, and to show that these styles are not so obsolete as seems to be supposed in some quarters.

RING SOCIETIES. JON AND MAINE R. R.

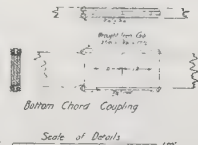
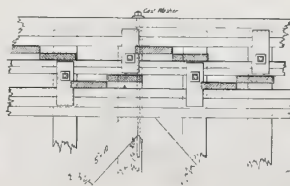
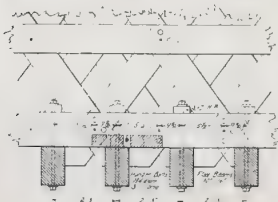
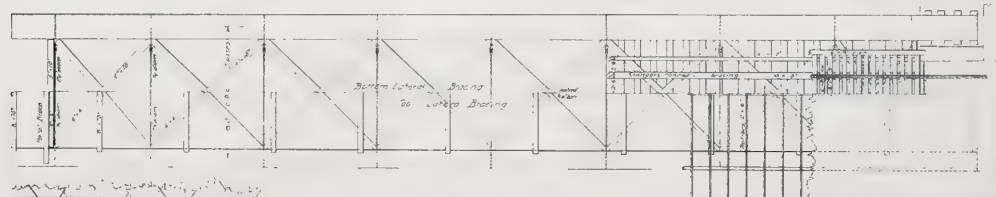
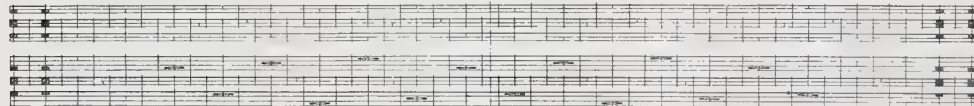


ss than 3".



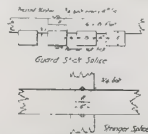


Scale of Feet

Source: *Author unless otherwise specified*

Bottom Chord Coupling

Scale of Detail:



Scale of vertical jump 20

BRIDGE DEFLECTIONS.*

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[Read May 15, 1895.†]

THE object of the following paper is to present the data and results of a series of experiments made to determine the effect of moving loads upon two railway bridges of about 122 and 164 feet span respectively. Many experiments have been made in this country and in Europe to determine the maximum vertical deflection of bridges under moving loads, and, in some cases, the lateral deflection; notably in experiments made by Professor Robinson,‡ but, in nearly all cases, as far as the author is informed, little or no data were determined in connection with the dimensions and weights of the moving loads, the true position of the moving load at the instant of maximum deflection, etc. In Professor Robinson's experiments, the speed of the moving load was determined by observers, making it possible to compute the true position of the load. In many cases the weights and dimensions of the cars and locomotives were obtained from the railway companies.

The majority of the diagrams represented in the tables accompanying this paper are automatic continuous records (for the point of the bridge being considered) of the following conditions:

1. The actual vertical motion of the point independent of the lateral and longitudinal motions.
2. The actual lateral motion of the point independent of the longitudinal and vertical motions.
3. The actual longitudinal motion of the point independent of the lateral and vertical motions.
4. Seconds of time.
5. The instant each wheel entered the span.
6. The instant each wheel passed the point being considered.
7. The instant each wheel left the span.

DESCRIPTION OF APPARATUS.

To obtain the above records the following described apparatus was employed, of which Fig. 1 represents an end view, Fig. 2 a rear view, and Fig. 3 a top view.

* The results embodied in this paper were obtained by Messrs. Rose and Tinsley, in 1892, and Messrs. Andrews and Hildreth, in 1894, in connection with their graduating theses. The apparatus was constructed to a great extent by these young men in the shops of the Rose Polytechnic Institute.

† Manuscript received June 22, 1895.—*Secretary, Ass'n of Eng. Socs.*

‡ Trans. Am. Soc. C. E., Feb., 1887. This is probably the most complete and valuable paper upon Bridge Vibrations which has ever been published.

Commencing at the bridge with any pin as *g* Fig. 1, a U-clamp *f* was securely fastened to the pin by the set screws *h*; to this clamp, which was slotted in the front face, the brass arm *d* was fastened by means of a bolt and thumb nut, so that the long arm was approximately opposite the center of the pin, thereby making the arm, to all intents and purposes, move in all respects with the bridge.

For transmitting vertical motion the adjustable arm *e* was fastened to *d*, the lower end of *e* bearing against the pin in lever *a'* (clearly shown in Figs. 1 and 3). Care was exercised to have *e* vertical, so that neither lateral nor longitudinal motion would move the lever *a'*; the lever *a'* transferred any vertical motion to the lever *a*, connected with the pen block *n*, which transferred the movement to the paper on the cylinders *k*, *l* and *m* (Fig. 3).

The arms of all levers being made equal, the record obtained was true size.

For lateral motion the bent lever *c* was employed, a pin in one end bearing against the plate *o*, Fig. 3; placed right angled with *d*, thereby eliminating the effect of vertical or longitudinal motion. The motion was transferred by the pen-block *n* to the paper.

Lever *b* transferred the longitudinal motion, the pin in one end moving in a slot in the arm *d*, as shown in Fig. 3.

The pen-blocks *n* moved on two round rods against spiral springs which effectually did away with lost motion of every kind.

In the above particulars it is believed that this apparatus is different from all others which have been employed. Nearly all, if not all, the devices employed by experimenters in this line have recorded the movements as arcs of circles and furthermore have not separated the individual movements. The rigid connection of the machine with the bridge is also a peculiarity of this apparatus.

The devices for recording the wheels and time require no description further than this: that all were dependent upon electric contacts.

The paper upon which the records were made was wound upon roller *m* passed over roller *l* and wound upon roller *k*. A crossed belt between *k* and *m* kept the paper taut by the friction between the belt and the rollers.

The roller *k* was fitted with a gear-wheel which was driven by a worm actuated by an $\frac{1}{2}$ -horse-power electric motor. The speed of the paper was about one inch per second. The pens employed were made of glass and filled with red aniline ink. The paper employed was a very tough sketching paper, but of such quality that the records could be blue-printed when red ink was used.

The entire machine was supported on an adjustable telescopic box which rested upon a light portable scaffolding made after the plan of oil

derricks, but assembled with bolts. This as well as the lower chord details of the Big Four Bridge are clearly shown in Fig. 4.

Fig. 4 shows the floor beam connections, lateral connections and post details as well as the machine ready to work.



FIG. 4.

DESCRIPTION OF BRIDGES.

Two bridges were examined which are briefly described as follows

Vandalia Bridge.—This was the west span of the bridge over the Wabash River at Terre Haute, Ind., on the T. H. V. and St. L. R. R. The principal dimensions of the trusses are: span, 164 feet; depth, 26 feet; length of panel, 20.5 feet. The bridge is a single-track, through, of the Pratt type, having floor-beams riveted to the posts and stringers riveted between the floor-beams.

The floor-beams are 4 feet deep and the stringers 3 feet in depth. The floor consists of the ordinary style of ties resting upon the stringers with wooden guard timbers on the outside of the rails.

The track crossing the bridge is practically straight and level, the west approach is straight for several hundred feet, but the east approach is curved until within 100 or 200 feet of the bridge, but since the span considered was the west one the approaches for 800 feet in either direction were straight.

About 200 feet east of the easterly span the road is crossed by a north and south track, and hence all trains going west come to a stop some 300 or 400 feet east of the bridge.

All east bound trains stop for this crossing 200 or 300 feet west of the span considered. All engines were working steam when crossing the bridge.

All records were taken at the lower chord-pin in the center of the north truss.

Big 4 Bridge.—This was the east span of the bridge over the Wabash at Terre Haute, Ind., on the C. C. C. and St. L. R. R. The principal dimensions of the trusses are: span, 122.5 feet; depth, 24 feet; length of panel, 17.5 feet. The general design is the same as the Vandalia Bridge, the floor system, however, being reinforced by safety stringers of wood and an inside guard-rail of old rails. The floor-beams are 3 feet deep. Fig. 4 shows the general details of the bridge.

The east approach to the span considered is straight track, but on a down grade. The west approach is across some five similar spans, including a draw-span, upon which the track is straight and level. All records were taken at the lower chord-pin, three panels from the east end of the north truss.

ROUTINE FOLLOWED IN THE EXPERIMENTS.

The apparatus having been put in position, the electric contacts, pens, etc., were tried and all imperfections corrected, then all hands busied themselves waiting for a train to appear.

As soon as a train was discovered approaching every man went to his post of duty. One man was required at the instrument to watch

the pens and start the motor (the machine usually being started a few seconds before the train reached the span), and two men took the numbers and types of the engine and cars. After the train had passed the motor was stopped and all data obtained, including the date, were immediately written upon the diagram. In many cases an observer was stationed at the depots who made a memorandum of the car numbers, wheel bases, etc.

BIG 4 BRIDGE.

Vertical Motion caused by Engines.—Usually only the engine and one car was on the bridge at the time of maximum deflection, though for eastbound trains one truck of a second car may have been upon the span near the end; but this car could influence the deflection but little, so its weight has not been included in the tables. All of the records at the first glance indicate a considerable vibration while the engine was on the span, but a closer examination indicates that the irregularity or roughness of the record is due not so much to the vibration of the bridge as to the friction of the pen or the levers, as the irregularities are in steps, both during the time of increasing deflection and decreasing deflection. In only two cases out of twenty-two records was there sufficient evidence of vibration at the maximum point of the diagrams to warrant any note of same; these were diagrams 77 and 83, where the increase in deflection was but 5.1 and 7.5 per cents. respectively; in both cases the amplitude of the vibration being about 0.06 of an inch. The direction in which the train was going had no effect upon the vertical motion.

It is to be noticed that for the same engine followed by the same tender and car that the vertical deflection is very nearly the same in all cases; this, of course, might be expected in the results given, as there is but little variation in speed, with the exception of diagrams for engine 92; this was a yard engine *pushing* two coal cars, and the speed varied from 0 to 20 miles per hour.

The static deflection was found to be 0.39 of an inch.

The maximum departure from this was 0.04 of an inch with the train going east at a speed of 18.5 miles per hour; either this is an accidental result or all conditions were favorable for vibration, as a speed of 20.1 miles per hour caused no vibration at all, and, furthermore, when the train was going west no vibration appeared, although the speed was nearly the same.

Apparently, in diagrams 63 and 75, two engines weighing the same followed by mail cars give contradictory results, as the train having the heavier car gave the smaller deflection. This can be explained in several ways. The engines being different, may not weigh exactly the same; the tenders may have been differently loaded and the amount of mail matter quite different in the two trains.

Conclusion.—For this span of 122.5 feet, divided into seven panels of 17.5 feet each, the engine causes no appreciable or dangerous vibration in the main trusses at the time of maximum deflection for speeds between 0 and 20 miles per hour.

Vertical Motion Caused by Cars and Lateral Motion Caused by Cars and Engine.—The lateral motion in all cases, with hardly an exception, was a maximum for the engine.

The records are rough and irregular, with little indications of period, though close examination and a little stretching of the imagination shows that the bridge swings from side to side between two and three times per second for all trains and all speeds.

Cumulative vibration was quite frequent for the cars, especially in freight trains, when the cars were very considerably different in loading; this cumulative vibration took place usually when the greatest disturbance in the vertical motion was experienced.

The amplitude of the side motion for the speeds observed was about constant, as the speeds varied but little.

The records for vertical motion for the train were very smooth, and in only two cases was there indication of vertical vibration, and these were questionable.

The loaded and empty cars were easily distinguished by the records.

The maximum deflection due to the train was, with hardly an exception, not greater than three-fifths that due to the engine, tender and one car.

Conclusion.—For this span of 122.5 feet, divided into seven panels of 17.5 feet each, the train causes no noticeable vertical vibration in the main trusses, but the engine, as well as the cars, creates an irregular side motion.

Longitudinal Motion.—In all cases this was towards the roller end of the span, as might have been expected; small in magnitude and of but little interest.

VANDALIA BRIDGE.

Vertical Motion caused by Passenger Engines.—As in the case of the Big 4 Bridge, the records were rough, indicating some vibration as the engine entered the span, but at the point of maximum deflection very little vibration appeared, the maximum effect being an increase in deflection of 9.25 per cent. for diagram 21a for an eight-wheel Pittsburg engine weighing 89,000 pounds.

Conditions of loading being the same, the vertical deflection remains constant for trains going in the same direction, but a marked difference was found to exist between the deflections for east and west bound trains,

the latter causing much greater deflections. This, however, is readily explained as the west bound trains were heavier and the engines had just left the round house and commenced their run with full tenders while the east bound engines were at the end of their run with but little in their tenders.

This may seem questionable, but it must be remembered that an empty tender usually weighs about the same as the water and coal it is intended to carry. This means a difference of from 10 to 15 tons in the weight of the tender on the road.

Some of the roughest records due to engines have been reproduced. The records for engines of Class "B" (including the maximum increase of 9.5 per cent. in Diagram 21*a* mentioned above) show the effect of direction; the east bound records showing a much smaller deflection than those for west bound trains. The records whose numbers have a subscript were taken in 1892 and show a somewhat different characteristic than those for 1894. This is not easily explained.

The records for 1892 are more indicative of vibration while those for 1894 show steps which indicate friction in the apparatus.

The record for engines of types C, F and G have also been reproduced. The characteristics of the records are the same for all classes, there being no method in the madness of the curves, the slight departure from smooth lines appearing at random, sometimes indicating vibration and again only friction of the machine; in all cases, however, the swing or amplitude of the vibration, if it can be so called, appears to be very small in comparison with the maximum deflection due to the engine.

Conclusion.—Based upon these records, it is evident that passenger engines cause no injurious vibration in the main trusses of this bridge.

Vertical Motion caused by Freight Engines.—The effect of these engines is practically the same as for passenger engines with a more frequent tendency to vibration.

Diagram 33*a* (reproduced) for engine 160 comes nearer indicating a regular vibration than any other, yet this cannot be called cumulative and is very small in amplitude.

Diagram 28 for engine 267 (reproduced) clearly shows the effect of friction in the machine.

Conclusion.—The same as for passenger engines.

Vertical Motion caused by Yard Engine 92.—This engine weighing 66,000 pounds on four drivers and about 40,000 pounds on the tender, was run at speeds varying from 11.6 to 36.9 miles per hour to determine if speed would affect the records.

This engine at all speeds gave rough records, but the amplitude of the vibration was small and not a maximum with the maximum speed.

The average vertical deflection was practically the same for all speeds varying between the limits of .280 and .305 of an inch and these extremes occurring at practically the same speed.

The application of brakes appeared to have no effect.

PASSENGER TRAINS.

Lateral Motion due to Cars and Engines.—The lateral motion, in all cases, was a maximum for the engine, though now and then the cars caused a little, especially the rear cars. In no case did the amplitude exceed one-half of an inch.

The speed had a marked influence upon this record, the greater the speed the greater the amplitude and the more irregular the records. This is clearly shown by the records reproduced.

Engines of the same type also had quite different effects as shown in Diagrams 25*a* and 21*a* for engines 142 and 185 of type *B* moving at practically the same velocities.

FREIGHT TRAINS.

Lateral Motion due to Cars and Engines and Vertical Motion due to Cars.—Here the records were practically the same for the engines as for passenger engines, but quite different records for the cars, vibration being quite frequent and the rear cars nearly always producing more or less disturbance. Diagrams 28, 44, 54, 18 and 33*a* have been reproduced as being the best examples of records having lateral motion due to cars.

The vertical disturbance due to cars was also quite different in many cases, a *small* cumulative vibration being quite frequent. This is well illustrated in Diagrams 54 and 33*a*.

This cumulative disturbance seems to be due not to the length of the car as measured in panel length of the bridge, but to the loading of several adjacent cars. The cause is hard to determine with certainty. The disturbance exists and the only question which can be discussed is, does this disturbance cause any serious damage to the structure?

Lateral Motion due to Engine 92.—These experiments certainly show that the amplitude of the lateral motion or swing varies almost directly with the speed, a speed of 36.9 miles per hour causes a lateral swing of .305 of an inch; as great as the vertical deflection.

Vertical Motion due to Pullman Cars.—The deflection caused by Pullman cars was practically constant and averaged about 0.36 of an inch.

Comparison of Theoretical and Actual Deflections.—The actual and theoretical deflections were compared for both bridges and it was found

that the actual was very much smaller than the theoretical deflection which was computed by Professor Johnson's $\frac{p u l}{E}$ formula.

Of course Professor Johnson's formula assumes that the structure is purely pin-connected, that is, each member of the truss is independent and only connected to the truss of which it forms a part by pins. Is this the case with the bridges in question? Certainly not, for the top chord is practically a continuous beam from hip to hip and the bottom chord must be seriously affected by the lines of stringers which form a continuous beam from two to three feet in depth from end to end of the bridge.

Owing to the continuity of the stringers the panel loads then are not of the magnitude usually assumed, and which were assumed, in the calculations. This might materially affect the stresses in the main-truss members, and hence the theoretical deflection. Again, owing to the continuous top chord and stringers, may it not be questioned if the $\frac{p u l}{E}$ formula is exactly correct, or even approximately correct, for the two bridges considered?

GENERAL DISCUSSION OF RESULTS.

Taking the records from both bridges as a whole there seems to be no indication of injurious stresses in the main truss members due to vibration produced by the moving load. The vibrations produced by the engines were exceedingly small, and that due to the cars, although greater in amplitude than that due to the engines, yet it always took place when the vertical deflection was much less than that produced by the heavy engines, so that the only injurious effects were those due to increasing and decreasing the stresses at the rate of about four times per second now and then. The range of stresses, however, being a very uncertain quantity.

For bridges of dimensions and types similar to those examined it does not seem necessary to add any material to the main truss members to provide for impact, according to the almost universal custom, and the author is of the opinion that the vibration of bridges, slight as appears for these two bridges and as large as Professor Robinson states in his paper for some bridges, may be entirely destroyed by putting in the proper floor system.

A very heavy and rigid floor, such as those designed to be ballasted with broken stone, or a very flexible floor hung to the chord pins, would without doubt consume all impact before it reached the main trusses.

The records of side motion indicate lateral weakness, and this is probably the case with all bridges of this type. The lateral motion is

caused, without doubt, by the nosing of the engine and the moving from side to side of the track of the cars owing to the widening of the gauge. The ordinary adjustable lateral system, designed to withstand wind only, is too light to resist this impact ; the solid floor ballasted would probably overcome this weakness.

At some future time it is hoped that the device used in these experiments may be applied to bridges of various spans and designs, with known loads moving at various speeds, as the writer believes records similar to those exhibited would determine some points in bridge design which might be changed with advantage to the life and working of the structure.

Another point which would be interesting to examine is the deflections simultaneously of both trusses. The records suggest that the whole bridge may have taken a slight twisting or spiral motion.

The author wishes to acknowledge the very courteous assistance given by the officials of the Vandalia System, the C. C. C. and St. L. Ry. Co., the Pullman Palace Car Co., the Wagner Palace Car Co., Baldwin Locomotive Works and the Pittsburg Locomotive Works, and also for the assistance in collecting and tabulating results by Mr. M. C. Andrews.

TABLE I.—VERTICAL MOTION.
PASSENGERS AND FREIGHT ENGINES—BIG 4 BRIDGE.

Reference Number.	Date.	Number of Engine.	Type of Engine.	Weight on Pilot Wheels.	Weight on Drivers.	Total Weight of Engine.	Weight of Tender.	Car Following Tender.	Weight of Car Following Tender.	Max. Vert. Def. due to Engine.	Av. Vert. Def. due to Engine at Max. Point.	Percentage Increase due to Vibration.	Approximate Speed in Miles per hour.	Direction.
69	May 4, 1894	196	8 W	39,900	79,700	119,600	85,240	Comb. car 113	50,000	0.54	0.54	..	20.4	East
B	" 3, 1894	196	"	39,900	79,700	119,600	85,240	" 118	53,500	0.55	0.55	..	20.9	West
A	" 3, 1894	197	"	39,900	79,700	119,600	85,240	" 113	50,000	0.57	0.55	3.6	31.9	East
66	" 4, 1894	197	"	39,900	79,700	119,600	85,240	" 113	50,000	0.57	0.57	..	23.1	West
70	" 3, 1894	116	"	33,000	55,300	88,300	60,000	Baggage 57	37,400	0.36	0.36	..	22.0	East
63	" 4, 1894	287	"	33,000	55,300	88,300	60,000	P. O. 8	52,000	0.38	0.38	..	24.6	West
75	" 3, 1894	379	"	33,000	55,300	88,300	60,000	P. O. 4	46,000	0.43	0.43	..	24.7	West
72	" 3, 1894	111	"	30,500	51,000	81,500	58,000	Baggage 63	52,000	0.42	0.42	..	19.6	East
64	" 4, 1894	299	"	22,900	63,300	86,200	63,900	Box	..	0.42	0.42	..	19.5	West
76	" 3, 1894	300	"	22,900	63,300	86,200	63,900	Empty coal	..	0.39	0.39	..	17.2	West
62	" 4, 1894	450	10 W	29,900	103,700	133,600	82,650	Box	..	0.58	0.58	..	15.2	East
77	" 3, 1894	450	"	29,900	103,700	133,600	82,650	"	..	0.61	0.58	5.1	20.6	West
68	" 4, 1894	?	"	..	..	..	..	"	..	0.58	0.58	..	8.9	East
73	" 3, 1894	408	10 W	29,900	103,700	133,600	82,650	"	..	0.58	0.58	..	16.2	East
60	" 4, 1894	435	"	..	..	..	..	"	..	0.59	0.59	..	17.9	West
74	" 4, 1894	442?	10 W	29,900	103,700	133,600	82,650	"	..	0.59	0.59	..	19.8	West
67	" 4, 1894	455	"	..	..	..	..	"	..	0.55	0.55	..	18.3	West
84	" 3, 1894	92	6 W	..	104,500	104,500	61,600	Pushing 2 coal cars	Weight of coal cars.	0.39	0.39	..	..	..
83	" 3, 1894	92	"	..	104,500	104,500	61,600	"	..	0.43	0.40	7.5	18.5	East
81	" 3, 1894	92	"	..	104,500	104,500	61,600	"	..	0.39	0.39	..	20.1	East
80	" 3, 1894	92	"	..	104,500	104,500	61,600	"	No. 1, 23,200	0.39	0.39	..	19.3	West
82	" 3, 1894	92	"	..	104,500	104,500	61,600	"	No. 2, 21,440	0.38	0.38	..	19.9	West

TABLE II.—VERTICAL MOTION.

PASSENGER ENGINES.—VANDALLA BRIDGE.

Reference Number.	Date.	Number of Engine.	Total Weight	Weight of Tender.	Weight of Car following Tender.	Maximum Vertical Motion.	Average Vertical Motion.	Percentage of increase due to vibration at Max. Point.	Approximate speed in miles per hour.	Direction.	Wheel Base of Engine.	Distance between forward and rear wheels.	Number of Pilot Wheels.	Number of Drivers.	Diameter of Drivers.	Maker.
31 ^a	April 28, 1892	4	60,600	44,000	37,350	0.36	0.34	5.9	24.6	East	21' 3"	43' 8"	4	4	64"	Danforth Loco. &
49	" 28, 1894	254	60,600	44,000	37,350	0.34	0.34	.	11.1	East	21' 3"	43' 8"	4	4	64"	
20	" 26, 1894	254	60,600	44,000	37,350	0.31	0.31	.	11.5	East	21' 3"	43' 8"	4	4	64"	
7	" 25, 1894	A { 254	60,600	44,000	37,350	0.32	0.32	.	11.5	East	21' 3"	43' 8"	4	4	64"	
43	" 24, 1894	254	60,600	44,000	37,350	0.40	0.39	2.6	13.5	West	21' 3"	43' 8"	4	4	64"	
12	" 25, 1894	254	60,600	44,000	37,350	0.40	0.40	.	19.0	West	21' 3"	43' 8"	4	4	64"	
25	" 26, 1894	21	60,600	44,000	37,350	0.39	0.39	.	22.0	West	20' 8"	45' 0"	4	4	62"	
33	April 27, 1894	142	89,000	59,500	P.C.C. Ex.	0.37	0.37	.	4.8	East	20' 7"	44' 2"	4	4	66"	Pittsburgh
22 ^a	" 27, 1892	185	89,000	59,500	P.C.C. Bag.	0.42	0.40	5.0	13.5	East	22' 9"	45' 5"	4	4	66"	
21 ^a	" 26, 1892	125	89,000	59,500	P.R. Comb.	0.58	0.54	9.2	23.0	West	22' 9"	45' 5"	4	4	66"	
25 ^a	" 28, 1892	142	89,000	59,500	P.R. Comb.	0.54	0.50	5.0	23.3	West	20' 7"	44' 2"	4	4	66"	
47	April 28, 1894	145	65,000	49,000	41,400	0.33	0.33	.	12.0	East	21' 1½"	.	4	4	.	Baldwin
28 ^a	" 27, 1892	143	65,000	49,000	61,200	0.39	0.38	2.7	14.5	East	21' 6"	.	4	4	.	
13 ^a	" 27, 1892	C { 145	65,000	49,000	P.C.C. P.O.	0.36	0.35	2.9	17.6	East	21' 1½"	.	4	4	.	
26 ^a	" 27, 1892	143	65,000	49,000	61,200	0.42	0.41	2.4	17.0	West	21' 6"	.	4	4	.	
14 ^a	" 28, 1892	145	65,000	49,000	47,500	0.41	0.41	7.3	28.4	West	21' 1½"	.	4	4	.	
16	April 25, 1894	162	63,000	49,000	57,300	0.36	0.36	.	13.5	East	22' 0½"	44' 0"	4	4	68"	Baldwin
5	" 23, 1894	161	63,000	49,000	41,400	0.32	0.32	.	13.8	East	22' 0½"	44' 0"	4	4	68"	
14	" 25, 1894	161	63,000	49,000	41,400	0.36	0.36	.	15.6	West	22' 0½"	44' 0"	4	4	68"	
15 ^a	" 26, 1892	163	63,000	49,000	61,200	0.42	0.40	5.0	23.1	West	22' 0½"	44' 0"	4	4	68"	

BRIDGE DEFLECTIONS.

40	April	27, 1894	181	84,600	59,500	38,400	0.39	0.39	6.9	East	22'	9"	44' 10 ¹ / ₂ "	4	68"
15	"	25, 1894	179	84,600	59,500	?	0.40	0.40	9.3	East	22'	9"	44' 10 ¹ / ₂ "	4	68"
"	"	28, 1894	181	84,600	59,500	?	0.40	0.40	10.6	East	22'	9"	44' 10 ¹ / ₂ "	4	68"
20	"	28, 1892	179	84,600	59,500	?	0.38	0.38	10.7	East	22'	9"	44' 10 ¹ / ₂ "	4	68"
27	"	26, 1894	182?	84,600	59,500	?	0.39	0.39	12.0	East	22'	9"	44' 10 ¹ / ₂ "	4	68"
26	"	29, 1894	179	84,600	59,500	56,000	0.40	0.40	12.0	East	22'	9"	44' 10 ¹ / ₂ "	4	68"
32	"	26, 1892	180	84,600	59,500	38,600?	0.44	0.415	6.0	East	22'	9"	44' 10 ¹ / ₂ "	4	68"
34	"	27, 1894	180	84,600	59,500	?	4.48	0.48	18.4	West	22'	9"	44' 10 ¹ / ₂ "	4	68"
48	"	28, 1894	179	84,600	59,500	38,600?	0.47	0.47	20.7	West	22'	9"	44' 10 ¹ / ₂ "	4	68"
34	"	27, 1894	182	84,600	59,500	?	0.46	0.46	21.0	West	22'	9"	44' 10 ¹ / ₂ "	4	68"
13	"	27, 1892	179	84,600	59,500	?	0.52	0.50	4.0	West	22'	9"	44' 10 ¹ / ₂ "	4	68"
55	"	28, 1894	181	84,600	59,500	70,600	0.52	0.52	22.7	West	22'	9"	44' 10 ¹ / ₂ "	4	68"
24	"	26, 1894	181	84,600	59,500	77,800	0.53	0.51	4.2	West	22'	9"	44' 10 ¹ / ₂ "	4	68"
Pittsburg															
52	April	28, 1894	187	105,000	59,500	38,400	0.43	0.43	7.3	East	23'	5"	46' 10"	4	4
23	"	26, 1894	187	105,000	59,500	P. O.	0.47	0.47	10.0	East	23'	5"	46' 10"	4	4
23	"	27, 1892	186	105,000	59,500	P.R.R. P.O.	0.46	0.45	2.2	East	23'	5"	46' 10"	4	4
18	"	28, 1892	187	105,000	59,500	P.R.R. P.O.	0.48	0.465	3.2	East	23'	5"	46' 10"	4	4
42	"	27, 1894	187	105,000	59,500	70,600	0.54	0.54	15.3	West	23'	5"	46' 10"	4	4
30	"	26, 1894	186	105,000	59,500	30,200	0.53	0.52	1.9	West	23'	5"	46' 10"	4	4
11	"	25, 1894	187	105,000	59,500	77,800	0.56	0.54	3.7	West	23'	5"	46' 10"	4	4
Pittsburg															
51	April	27, 1894	191	139,000	80,800	P. O.	0.54	0.54	13.3	East	23'	8"	50' 7"	4	6
38	"	28, 1894	192	136,000	80,800	P. O.	0.55	0.55	13.8	East	23'	8"	50' 7"	4	6
8	"	25, 1894	192	139,000	80,800	P. O.	0.53	0.53	13.9	East	23'	8"	50' 7"	4	6
21	"	26, 1894	191	139,000	80,800	50,000	0.58	0.56	3.6	East	23'	8"	50' 7"	4	6
24	"	26, 1894	192	139,000	80,800	52,000?	0.62	0.60	3.3	West	23'	8"	50' 7"	4	6
28	"	27, 1894	191	139,000	80,800	52,000?	0.65	0.65	17.8	West	23'	8"	50' 7"	4	6
0	"	25, 1894	191	139,000	80,800	P. O.	0.64	0.64	21.2	West	23'	8"	50' 7"	4	6

TABLE III.—VERTICAL MOTION.
FREIGHT ENGINES—VANDALIA BRIDGE.

No. of Diagram.	Date.	Number of Engines.	Total Weight of Engine.	Weight of Tender.	Kind of Car Following Tender.	Max. Vertical Motion.	Average Vert. Motion at Max. Point.	Percentage of Increase due to Vibration at Max. Point.	Approximate Speed in Miles per hour.	Direction.	Wheel Base of Engine.	Distance from Forward Pilot to Rear Tender Wheel.	No. of Pilot Wheels.	No. of Drivers.	Diameter of Drivers.	Maker.
44	April 27, 1894	H { 33	65,000	44,000	Box	0.49	0.49	.	14.9	West	21' 9"	.	4	4	.	Baldwin
54	" 28, 1894	" { 33	65,000	44,000	"	0.40	0.40	.	16.1	West	21' 9"	.	4	4	.	"
35a	" 27, 1892	43	75,000	49,000	.	0.44	0.42	4.8	18.8	West	22' 7"	.	2	6	.	"
38a	" 26, 1892	160	68,000	50,000	.	0.44	0.42	4.8	18.1	West	23' 1"	.	4	6	.	"
39	" 27, 1894	H { 170	65,000	44,000	Box	0.43	0.43	.	6.1	East	21' 9"	.	4	4	.	"
29	" 26, 1894	" { 170	65,000	44,000	"	0.44	0.42	4.8	14.5	West	21' 9"	.	4	4	.	"
13	" 25, 1894	I { 171	75,700	49,000	"	0.42	0.42	.	10.4	East	21' 9"	.	2	6	.	Baldwin
45	" 27, 1894	" { 171	75,700	49,000	"	0.50	0.50	.	15.2	West	21' 9"	.	2	6	.	"
35	" 27, 1894	{ 153	76,000	50,000	"	0.46	0.46	.	14.0 ?	East	23' 8"	45' 11"	4	6	50"	Baldwin
32a	" 27, 1892	{ 174	76,000	50,000	"	0.49	0.48	1.0	16.7	West	23' 8"	45' 11"	4	6	50"	"
36	" 27, 1894	J { 174	76,000	50,000	"	0.34	0.34	.	3.3	East	23' 8"	45' 11"	4	6	50"	"
34a	" 27, 1892	{ 175	76,000	50,000	.	0.48	0.46	4.3	9.8	East	23' 8"	45' 11"	4	6	50"	"
50	" 28, 1894	{ 177	76,000	50,000	Box	0.48	0.48	.	12.6	East	23' 8"	45' 11"	4	6	50"	"
22	" 26, 1894	{ 269	105,000	74,300	Furniture	0.41	0.41	.	9.3	East	.	.	.	.	.	.
28	" 26, 1894	{ 267	105,000	74,300	Box	0.56	0.56	.	12.0	West	20' 9 1/2"	48' 2 1/2"	4	6	.	.
18	" 25, 1894	K { 268	105,000	74,300	Coal	0.52	0.52	.	15.2	West	.	.	.	.	.	.
19	" 2, 1894	" { 269	105,000	74,300	"	0.58	0.57	1.6	13.8	West	.	.	.	.	.	.

TABLE IV.—VERTICAL AND LATERAL MOTION.

SPECIAL YARD ENGINE NO. 19.—VANDALIA BRIDGE.

Number of Diagram.	Direction.	Speed in Miles per Hour.	Max. Amplitude of Lateral Motion.	Maximum Vertical Motion.	Average Vert. Motion at Max. Point.	Percentage of Increase due to Vibration at Max. Point.	Remarks.
2	East	11.6	0.135	0.29	0.285	2.0	Engine going ahead.
1	"	17.8	0.03	0.30	0.28	7.1	
6	"	21.9	0.10	0.33	0.30	10.0	
4	"	25.1	0.13	0.32	0.295	8.5	
5	"	34.6	0.24	0.31	0.29	7.0	
3	"	36.9	0.305	0.32	0.30	6.6	Engine going ahead and brakes applied as soon as on bridge.
8	"	19.1	0.14	0.32	0.30	6.6	
7	"	35.7	0.24	0.32	0.30	6.6	
10	West	18.5	.	0.51	0.305	1.6	Engine backing.
9	"	20.2	0.19	0.31	0.29	7.0	
11	"	29.1	0.17	0.32	0.29	10.0	Engine backing and brakes applied as soon as on bridge.
12	"	15.4	0.15	0.30	0.29	.	
Mean			0.313	0.294	6.4		

TABLE V.—VERTICAL AND LATERAL MOTIONS DUE TO CARS.

PASSENGER TRAINS.—VANDALIA BRIDGE.

Reference Number.	Class of Engine.	Av. Vert. Def. due to Engine.	Max. Vert. Def. due to Train.	Min. Vert. Def. due to Train.	No. of Cars in Train.	Max. Lateral Motion.	REMARKS.	
							Vertical Motion due to Train.	Lateral Motion due to Train and Engine.
31a	A	0.34			2	0.11	Smooth record.	Due to engine.
49	"	0.34			2	0.09	"	"
20	"	0.31			2	0.07	"	Fairly regular.
7	"	0.32			2	0.09	"	Due to engine.
43	"	0.39			2	0.12	"	Engine and train.
12	"	0.40			2	0.08	"	"
25	"	0.39			2	0.09	"	Fairly regular.
33	B	0.37	No record.	No record.	7	. . . . .	. . . . .	Very small.
22a	"	0.40	0.22	0.22	6	0.14	Very uniform train.	Principally due to engine. A little from train.
21a	"	0.54	0.38	0.31	5	0.10	Last two cars Pullmans.	Due to engine and rear cars.
25	"	0.50	0.38	0.30	5	0.10	Last two cars Pullmans.	"
							= 0.38.	"
							= 0.38.	"
47	C	0.33	Unif. dec'g.	Unif. dec'g.	2	Small	Smooth record.	Due to engine, decreasing as train passed.
28a	"	0.38	"	"	2	0.15	. . . . .	Principally due to engine.
13a	"	0.35	0.20	0.20	5	0.08	Smooth record.	"
26a	"	0.41	. . . . .	. . . . .	2	. . . . .	"	"
14a	"	0.41	0.21	0.20	5	0.09	"	"
16	D	0.36	. . . . .	. . . . .	1	. . . . .	"	Very slight.
5	"	0.32	. . . . .	. . . . .	2	. . . . .	"	Small, irregular, and due to entire train.
14	"	0.36	. . . . .	. . . . .	2	0.14	"	Due to entire train.
15a	"	0.40	. . . . .	. . . . .	2	0.15	"	"
40	E	0.39	0.23	0.20	6	0.13	"	Principally due to engine.
15	"	0.40	0.22	0.22	5	. . . . .	"	Very small.
9	"	0.40	0.25	0.19	6	0.15	"	Principally due to engine.

TABLE V.—VERTICAL AND LATERAL MOTIONS DUE TO CARS.—CONTINUED.

PASSENGER TRAINS.—VANDALIA BRIDGE.

Reference Number.	Class of Engine.	Av. Vert. Def. due to Engine.	Max. Vert. Def. due to Train.	Min. Vert. Def. due to Train.	No. of Cars in Train.	Max. Lateral Motion.	REMARKS.	
							Vertical Motion due to Train.	Lateral Motion due to Train and Engine.
20a	E	0.38	0.21	0.19	6	0.10	Smooth record.	Principally due to engine.
27	"	0.39	0.21	0.21	5	0.10	"	"
46	"	0.40	0.20	0.20	5	0.10	"	"
24a	"	0.42	0.24	0.22	6	0.26	"	"
32	"	0.48	0.31	0.31	8	0.14	"	"
48	"	0.47	0.23	0.23	5	0.13	"	"
34	"	0.46	0.23	0.23	5	0.12	Center missing.	Irregular.
19a	"	0.50	0.31	0.29	4	0.14	"	"
55	"	0.42	0.33	0.30	4	0.12	"	"
24a	"	0.51	0.36	0.33	4	0.16	"	"
52	F	0.43	0.29	0.25	6	0.17	"	Principally due to engine, but produced by cars also.
23	"	0.47	0.34	0.24	6	0.16	"	Small.
23a	"	0.45	0.36	0.31	7	0.16	"	Principally due to engine.
18a	"	0.47	0.33	0.9	8	0.17	"	"
42	"	0.54	0.33	0.27	5	0.15	"	Engine and rear cars.
30	"	0.52	0.35	0.33	7	0.14	"	Principally due to engine.
11	"	0.54	0.35	0.28	4	0.14	"	Engine and rear cars.
51	G	0.54	0.35	0.28	7	0.25	"	Principally due to engine.
38	"	0.55	0.36	0.28	7	0.13	"	Very irregular and due to engine. Due to engine and rear cars. Fairly regular.
8	"	0.53	0.36	0.28	7	0.19	"	Due to engine.
21	"	0.56	0.37	0.19	7	0.16	"	Engine and rear cars.
24	"	0.60	0.23	0.19	9	0.18	"	"
8	"	0.65	0.23	0.19	8	0.23	"	Due to engine.
10	"	0.62	0.23	0.19	8	0.13	"	"

TABLE VI.—VERTICAL AND LATERAL MOTIONS DUE TO CARS.
FREIGHT TRAINS.—VANDALIA BRIDGE.

Reference Number.	Number of Engine.	Av. Vert. Def. due to Engine.	Max. Vert. Def. due to Cars.	Min. Vert. Def. due to Cars.	Number of Cars.	Max. Lateral Motion.	REMARKS.	
							Vertical Motion—due to Train.	Lateral Motion—due to Train and Engine.
44	33	0.49	. . .	. . .	20	0.16	Culm. vib. due to rear cars. Max. swing = 0.06.	Engine and rear cars of train.
54	33	0.40	. . .	. . .	32	0.10	Culm. vib. 13th, 19th and 30th seconds. Swing about 0.06.	Engine and at 19th second.
35a	43	0.42	0.48	0.32	26	0.12	Ind. of culm. vib. near head of train. Record rough throughout.	Engine record irregular. Train record missing.
33a	160	0.42	0.40	0.25	23	0.16	Culm. vib. due to cars, but not at regular intervals. Max. swing about 0.06.	Irregular. Due to engine and train.
39	170	0.43	0.40	0.17	21	Small	Trace of vibration between 7th and 16th cars (loaded).	Evident between 7th and 16th cars.
29	170	0.42	0.40	. . .	18	0.11	Culm. vib. due to 7th car. Amplitude = 0.08. Period = 3 per second.	Engine and rear cars.
13	171	0.42	0.32	0.20	25	0.12	Vib. only evident by pen friction steps.	Engine and forward cars.
45	171	0.50	0.39	0.16	29	0.20	Very slight trace of vib. shown by pen friction.	Due to engine and center of train.
35	153	0.46	0.45	0.40	30	0.10	No vib., except as shown by pen friction.	More or less due to entire train. Culm.
32a	174	0.49	0.44	0.24	28	0.19	Some vib., but very irregular.	Max. for engine. Some for cars throughout.
36	174	0.44	0.48	0.40	29	Small	Smooth record.	Max. for tail cars.
3'a	175	0.46	0.36	0.15	21	0.12	1 case of culm. vib. near engine. Remainder of record smooth.	Due to engine and also some cars.
50	177	0.48	. . .	. . .	. . .	0.09	No vib., except as indicated by pen friction steps.	Culm. vib. at regular intervals.
22	269	0.41	0.28	0.16	23	0.07	3 or 4 cases of culm. vib. at loaded cars.	Engine and cars. 2.2 vib. per second for cars.
28	267	0.56	0.43	0.24	32	0.10	Max. def. due to tank cars.	Corresponding to vertical vibration.
18	268	0.52	. . .	. . .	35	0.13	Slightly culm. vib. 3 cases at irregular intervals.	Engine principally. No relation between V. and L. motion.
19	269	0.57	0.31	0.20	41	0.15	Some vib. near center of train due to refrigerator cars.	Engine and at center of train.

TABLE VII.—VERTICAL AND LATERAL MOTION DUE TO CARS.

FREIGHT AND PASSENGER CARS.—BIG 4 BRIDGE.

Reference Number.	Number of Engine.	Av. Vert. Def. at Max. Point due to Engine.	Max. Vert. Def. due to Cars.	Min. Vert. Def. due to Cars.	Number of Cars.	Max. Lateral Motion.	Vertical Motion—due to Cars.	REMARKS.	Lateral Motion—due to Cars and Engine.
*69	196	0.54	0.27	0.20	5	0.17	No vibration. Steps due to pen friction.	Due to engine and rear cars.	
*B	196	0.55	0.26	0.20	6	0.16	Culm. stepped. Due to pen friction.	Due to engine and cars.	
*A	197	0.55	0.29	0.25	5	0.18	Pen friction and irregular vib. for engine.	Engine and last cars.	
*66	197	0.57	0.30	0.25	5	0.20	Smooth record.	Engine principally. Slight for cars.	
*70	116	0.36	.	.	4	0.14	" "	Max. for engine. Little for cars.	" "
*63	287	0.38	0.19	0.19	4	0.16	" "	" "	" "
*75	379	0.43	.	.	4	0.13	" "	" "	" "
*72	111	0.42	0.20	0.20	5	No	" " Excursion train.	No record.	
64	299	0.42	0.20	0.15	8	0.16	Trace of vib. due to loaded coal car.	Max. for engine. Decreasing for cars.	
76	300	0.39	0.14	0.14	7	0.17	Smooth record.	Max. for engine. Some due to cars.	
62	450	0.58	0.36	0.18	30	0.26	" "	Engine and rear cars. For cars slight.	
77	450	0.58	0.30	0.19	28	.	Trace of vibration.	No record for engine. For cars slight.	
68	?	0.58	0.34	0.34	11	0.20	Smooth record.	Culm. vib. for rear cars.	
73	408	0.58	0.36	0.25	13	0.18	" "	2 cases of culm. vib. near end of train.	
60	435	0.59	0.26	0.19	26	0.17	" "	Engine and cars.	
74	?	0.59	0.31	0.16	?	.	Slight trace of vib.	No record.	
67	455	0.55	.	.	28	0.19	Smooth record.	Culm. for 5th car, a loaded coal car.	
84	92	.	.	.	2	0.0	Speed—0.0 miles per hour.	Going—standing.	
83	92	.	.	.	2	0.15	" 18.5 "	" East.	
81	92	.	.	.	2	0.14	" 20.1 "	" East.	
80	92	.	.	.	2	0.16	" 19.3 "	" West.	
82	92	.	.	.	2	0.18	" 19.9 "	" West.	

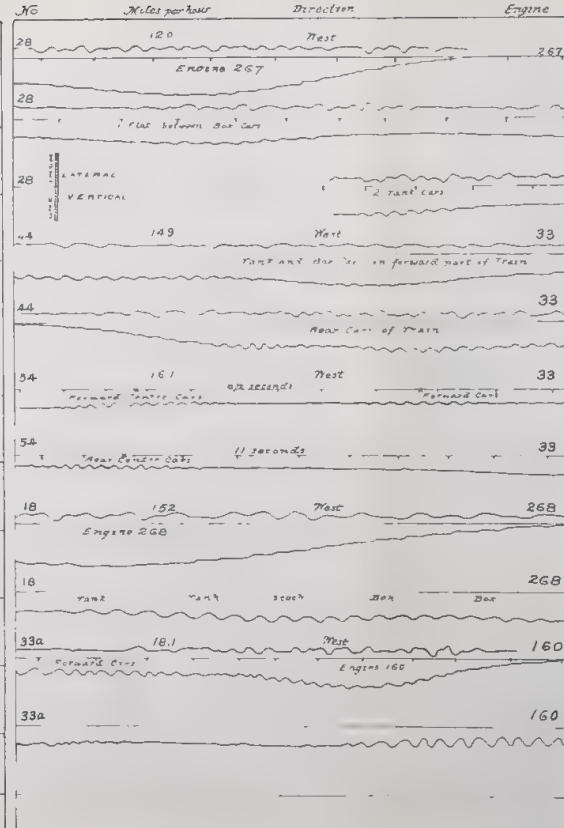
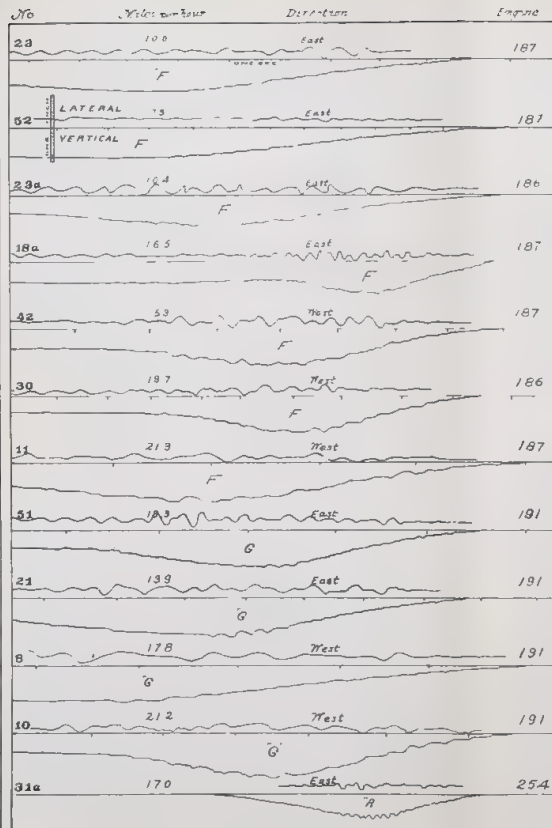
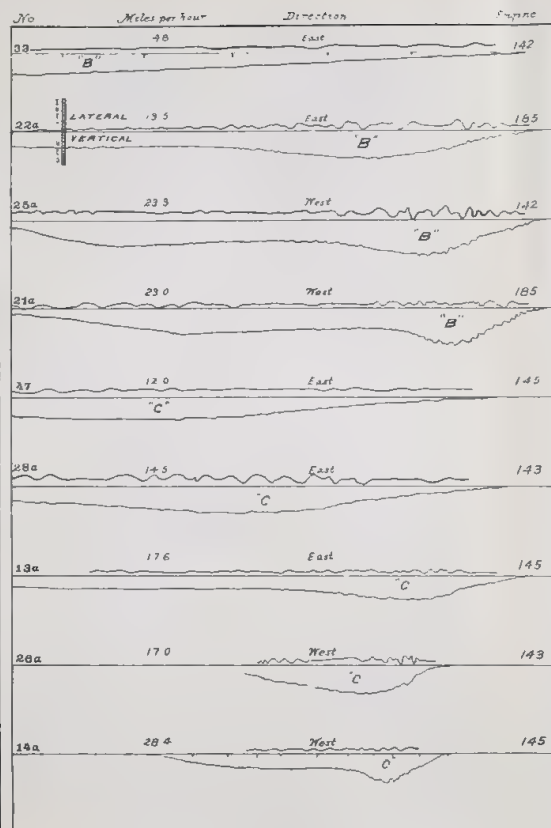
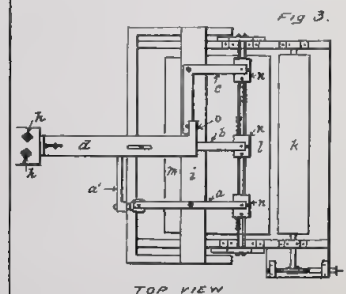
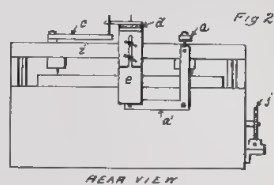
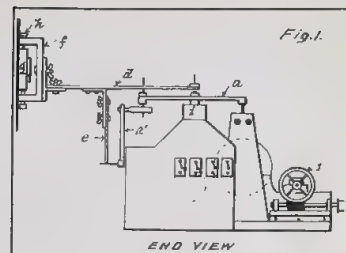
* Records for Passenger Trains.

TABLE VIII.—VERTICAL MOTION DUE TO PALACE CARS.

PULLMAN CARS.—VANDALIA BRIDGE.

Reference Number.	Name of Cars.	Weight of Car.	Length of Car over all.	Max. Vert. Def. when Cars were Sym. Placed about Center of Bridge.
25a	Almond	91,650	65' 11''	
	Zida			0.38
23a	Almond	91,650	65' 11''	
	Leixe	94,350	75' 5''	0.34
24a	Clearmont	91,650	65' 11''	
	Bala	95,030	75' 5''	0.36
51	Clearmont	91,650	65' 11''	
	Bala	95,030	75' 5''	0.35
8	Clearmont	91,650	65' 11''	
	Colon	96,550	75' 5''	0.36
42	Leicester	92,300	65' 11''	
	Gila	95,030	75' 5''	0.33
21	Leicester	92,300	65' 11''	
	Milo	95,030	75' 5''	0.37
11	Piedmont			
	Ciny	99,760	75' 5''	0.35
21a	Tremont	89,375	65' 11''	0.38
	Cedro	95,550	75' 5''	
18a	Tremont	89,375	65' 11''	0.36
	Cedro	95,550	75' 5''	
11	Tremont	89,375	65' 11''	0.35
	Ciny	99,760	75' 5''	

Engine	No	Mile
187	28	1:
187	28	Flat
186	28	<div> <div>IN OUT WINDS</div> <div> LATERAL VERTICAL </div> </div>
187	44	1
187	44	
186	54	Forward Cent
187	54	Rear Cent
191	18	Engine 2
191	18	Tank
191	33a	Forward Cars
191	33a	
254		



AN ENCASED STANDPIPE WITH SPECIAL PROVISIONS FOR WIND PRESSURE.

BY EDWARD FLAD, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read June 5, 1895.*]

STANDPIPES are constructed in connection with Water Works systems in order to relieve the pumps and pipe systems from excessive variations of pressure, or else to provide for storage of water.

If the object is merely to equalize the pressure, the standpipe need seldom be more than 5 or 6 feet in diameter, even for the larger cities, and it should, if possible, be placed in close proximity to the pumping station. Where storage of water is desired, the standpipe will usually vary from 10 to 30 feet in diameter, and it may be placed at any convenient location, proximity to the pumping station being of no particular advantage.

In the smaller cities standpipes are usually constructed for storage purposes, generally with a view to storing sufficient water for the consumption during the night hours, permitting of the banking of fires under the boilers, and reducing the operating expenses.

The Water Tower at St. Charles, Missouri, which is described herein, was constructed for storage purposes. The St. Charles Water Works were built by a private corporation under the franchise plan in 1881, and were at that time provided with an elevated tank located on the site of the present Water Tower, about $1\frac{1}{2}$ miles from the pumping station.

The tank was of wood, 20 feet in diameter and 16 feet high, and was supported upon a brick substructure, 20 feet square and 40 feet high. After having served its purpose for the period of about eight years, the structure collapsed, and from that time until the completion of the present tower, the works have been operated on the direct pressure system.

It is generally supposed that the failure was due to the poor quality of the brick used in the substructure, and to their gradual disintegration, owing to the action of frost upon the brick when saturated with water which leaked or overflowed from the standpipe.

When the writer was intrusted with the design of a new storage tank, he had in mind a number of failures of similar structures, and determined to benefit as far as possible from the lesson taught by such failures. Out of twenty-five failures of standpipes referred to by Prof.

* Manuscript received June 22, 1895.—*Secretary, Ass'n of Eng. Soc's.*

William D. Pence in his articles in the *Engineering News*, nine accidents were presumably due, at least in part, to the formation of ice, six being total failures; and six accidents were due to the effects of wind pressure, one of the six being a total failure.

A study of the failures which have been recorded leads to the conclusion that where no serious apparent fault in the design had occurred, when judged by the practice of leading engineers, the failures have been due to one or more of the following causes:

- (1) Inferior material.
- (2) Formation of ice.
- (3) Lack of proper provision against wind pressure.

If proper attention is given to these three causes of failure there would seem to be no reason for doubting the ability of the engineer to design a standpipe which would be as safe as an elevated tank or any other engineering structure.

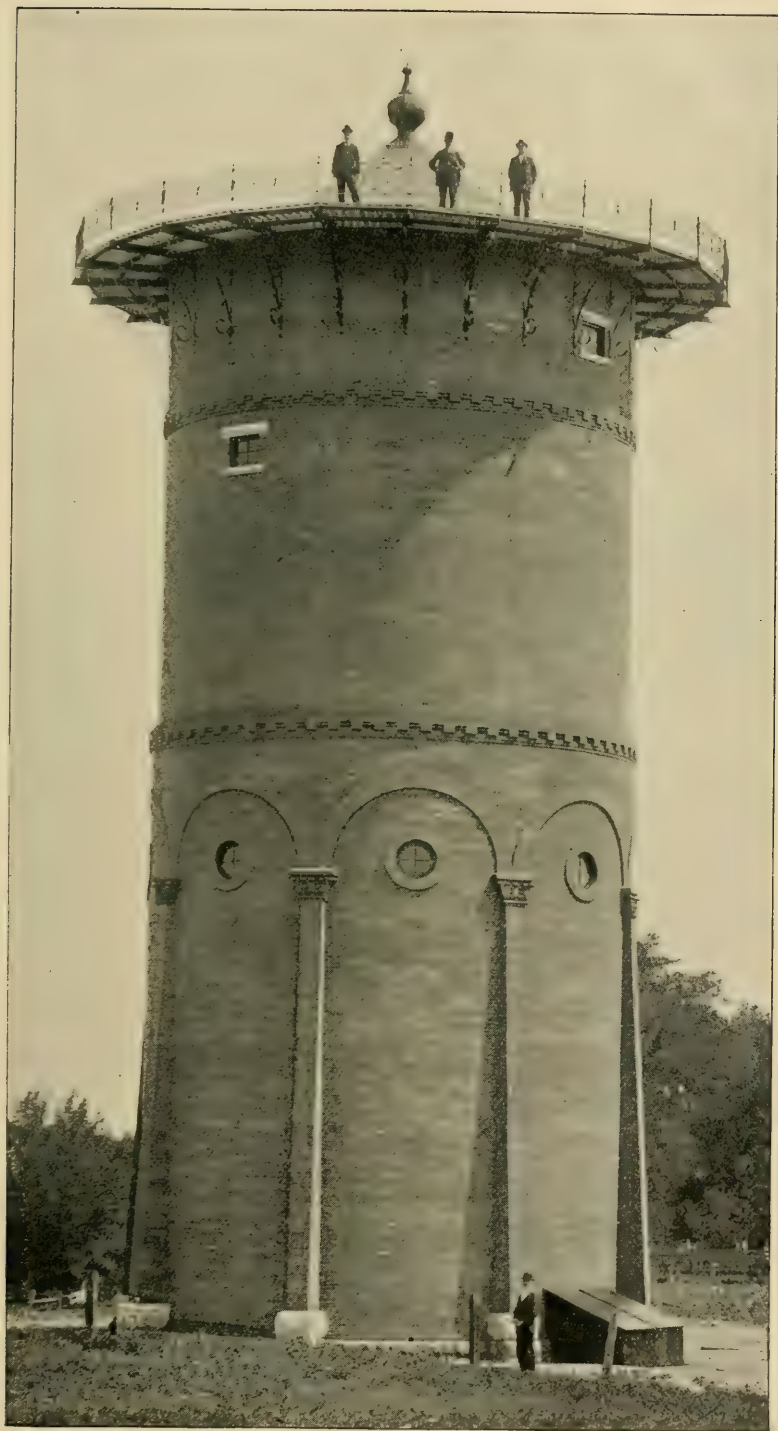
(1) In order to secure proper material it is of course only necessary to specify distinctly the quality of material required, and then to insist upon a rigid and careful inspection, and full compliance with the specifications.

(2) Where the standpipe is subject to extreme cold weather, a casing of wood, brick or other suitable material will usually offer sufficient protection against the formation of large amounts of ice, but if necessary suitable arrangements for heating can readily be introduced in connection with the casing.

(3) It has been customary to assume that a few stiffening angles and proper anchorage is sufficient to provide for wind pressure, the assumption being that the tank will hold its circular shape. For tanks of large diameter, however, further provision against wind pressure would seem to be desirable, in view of the many failures which have occurred, in order to avoid the collapsing of the upper sections or the vibration and swaying of the shell which is liable to occur during high winds, when the standpipe happens to be only partly filled with water. The provision for wind pressure adopted by the writer will be set forth in the description of the St. Charles Water Tower.

The drawings and photographs herewith show the design of the St. Charles Water Tower as constructed. The tank is 25 feet in diameter and 70 feet high, having a capacity of 250,000 gallons. It is encased in brickwork, a space of 2 feet being left between the tank and the inside of the brick casing. The foundation is built entirely of Louisville cement concrete faced with coursed rubble masonry. The roof is of metal and is covered with slate placed upon metal purlins.

The plates of the shell are of soft open-hearth steel, having a tensile strength between 60,000 and 68,000 pounds, and an elongation of not less



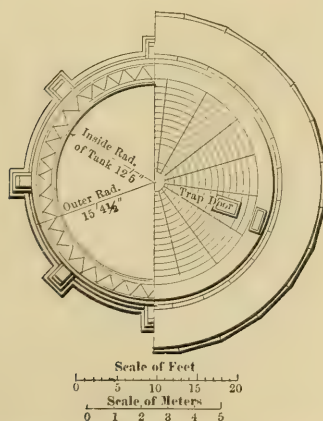
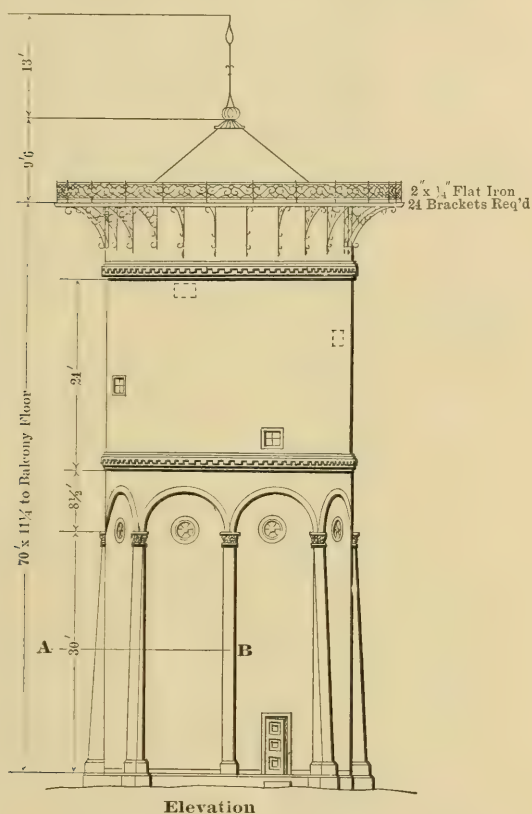
ST. CHARLES WATER TOWER.

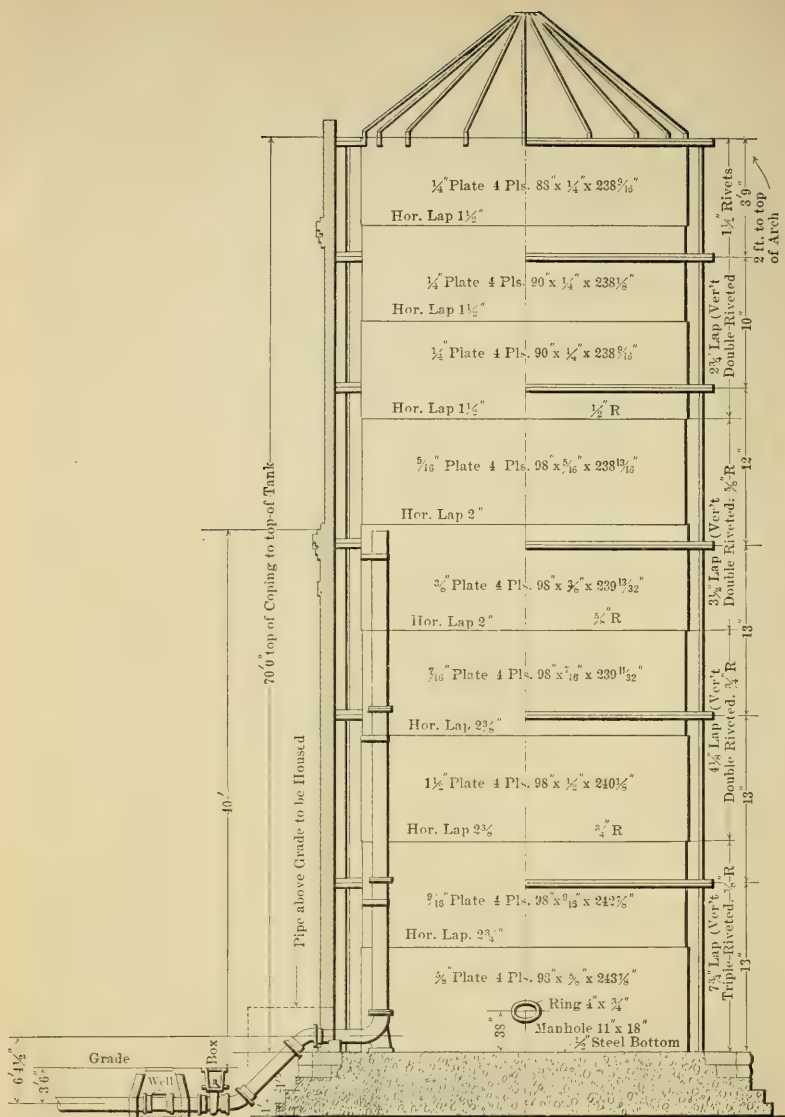


ST. CHARLES WATER TOWER.

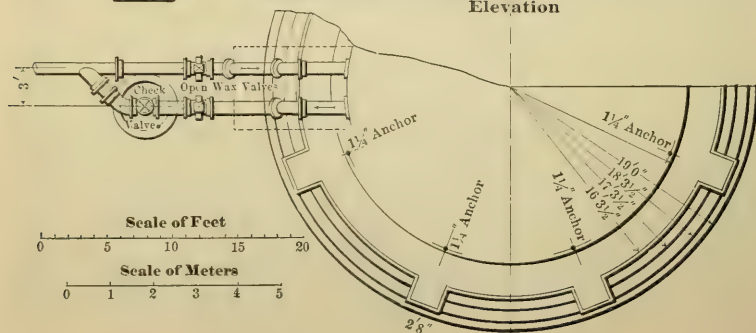
VIEW SHOWING STEEL TANK AND CIRCULAR GIRDERS BEFORE THE CONSTRUCTION
OF THE BRICK CASING WAS COMMENCED.

than 26 per cent. in 8 inches, and a reduction of area at fracture of not less than 50 per cent. Specimens were bent double and pressed flat without sign



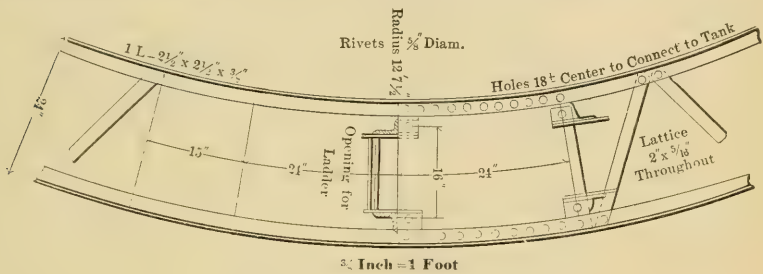


Elevation



of fracture. There are nine rings in the shell, 4 plates to the ring. The plates of the six lower rings are 8' 2" wide and approximately 20 feet long. The sheets vary from $\frac{1}{4}$ " thick at the top to $\frac{5}{8}$ " thick at the bottom section.

The special provision for wind pressure, which it is supposed is used here for the first time, consists of a number of circular girders placed at intervals on the outside of the tank and riveted to same. These girders are made up of angles and lattice bars, one angle being used next to the tank and two angles for the outer flange of the girder.



PLAN OF CIRCULAR GIRDER.

The brick casing rests against these girders. Wind pressure on the casing is therefore transmitted to the standpipe through the girders, and these latter hold the metal shell in its circular form and enable it to successfully resist the stress due to wind pressure. The girders therefore serve the double purpose of bracing the shell and casing.

Standpipes should be designed to successfully resist wind pressure when empty. The first effect of the wind is a tendency to collapse the shell, destroying the circular shape of the standpipe, and the upper thinner sections are of course the least able to resist such action. If sufficient rigidity is provided to prevent the collapsing of the shell, the standpipe will act as a cantilever, the leeward side being in compression. Adding such compressive stress to the compression produced at any section, by the weight of the metal above, we can readily calculate the total compression on the windward side.

There are no available data, however, which will enable us to determine how much compression is allowable upon a column 10 to 20 feet in diameter and 50 or 150 feet high, built of thin sheet metal.

The thickness of the metal in the shell required to resist collapsing, could be approximated by assuming a section contained between two horizontal planes a foot or more apart, and calculating the semi-circular strip on the windward side as an arch. Such calculations would show that the upper sections of our standpipes should be built with considerably thicker plates than has usually been customary.

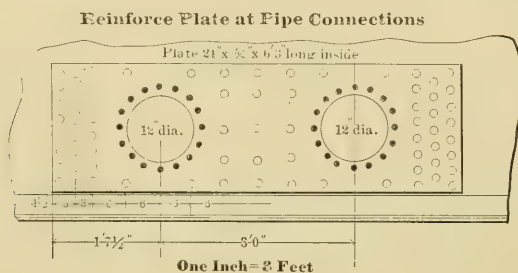
By introducing horizontal circular girders at short intervals we provide an economical method for holding the tank circular and preventing the collapsing of the shell, on the windward side, and at the same time resolve the standpipe into a series of short columns, the compressive resistance of which, under the cantilever action, may be assumed to more closely approximate the crushing strength of the material.

These circular girders on the standpipe hold a position similar to that occupied by the stiffeners on the web of a plate girder.

As the casing is braced laterally by the girders and metal shell, the brickwork is not required to be self-supporting, except so far as the dead load is concerned, and may therefore be made very light. The brickwork for the casing of the St. Charles standpipe was made only 13 inches thick for the lower 40 feet and 9 inches thick for the upper 30 feet. The pilasters and arches were introduced merely for architectural effect.

An inclined ladder is provided between the metal shell and casing, with a landing at each girder, so as to make the structure of easy and safe access for inspection and repairs.

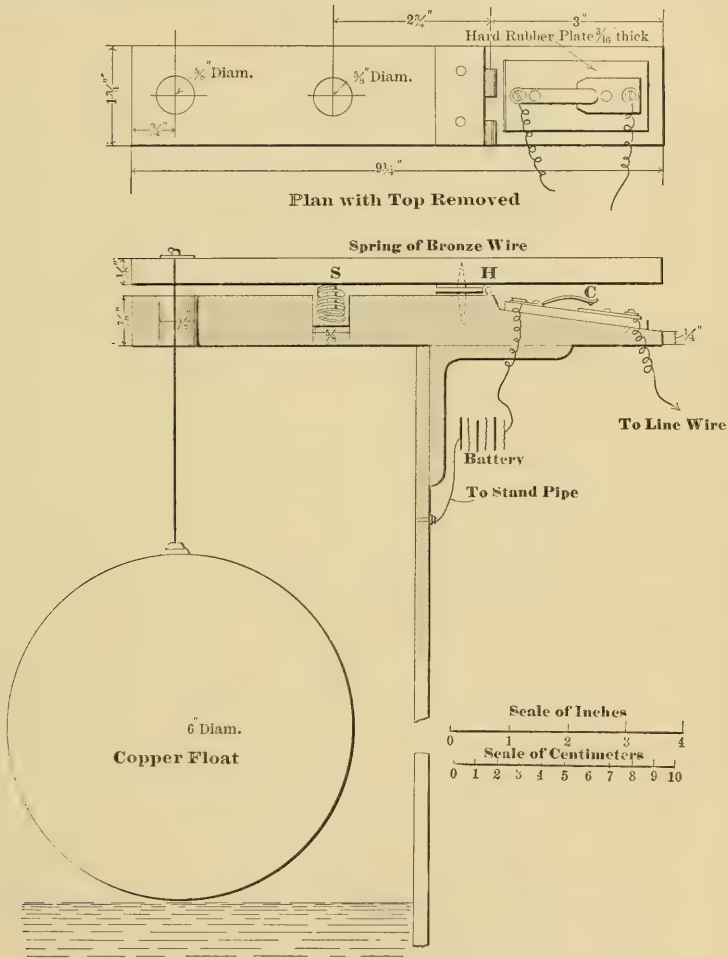
There are two 12 inch water connections to the standpipe at the bottom, placed so as to be easily accessible. They enter the standpipe at the side and are housed in for protection against frost. Both of these lead to the same water main. The connection through which the water enters the standpipe passes up into the standpipe, discharging at an elevation of 40 feet above the base. The other connection terminates



at the bottom of the standpipe, is provided with a check valve and serves as an outlet for the water when there is less than 40 feet of water in the standpipe. With this form of connection the full capacity of the tank is utilized for storage, and still a sufficient pressure is insured for fire purposes whenever the pumps are operated.

A high water alarm is provided, consisting of a float which actuates a lever and makes an electric contact, ringing an alarm bell at the pumping station whenever the water reaches within 3 feet of the top of

the tank. A single wire is used, the current being returned through the water main.

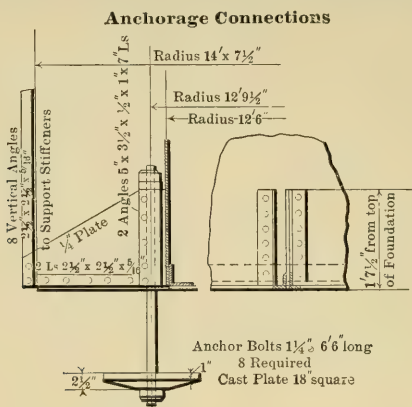


HIGH WATER ALARM.

The method used in erecting the shell is well shown in the photograph. A light scaffold was built inside of the tank, and a cage swung on the outside, the plates being raised with the aid of a jin-pole. A forge was placed on the cage and the rivets were driven from the inside.

After the bottom section was riveted together it was tested with water and made tight and was then lowered upon the concrete bed which had been previously leveled and smoothed with a trowel. Portland cement grouting was then introduced between the top of the foundation and the

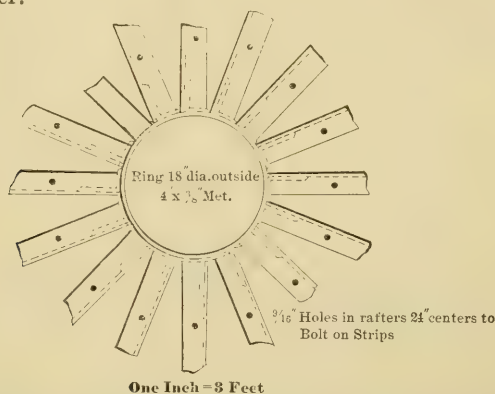
bottom of the tank, 17-1 $\frac{1}{4}$ " holes having been provided in the bottom for this purpose. These holes were afterwards fitted with screw plugs.



The sheets of the bottom were lap-welded and the rivet heads were not countersunk.

After the iron work was completed the brick casing was erected with the aid of exterior scaffold.

The foundation rests on good stiff clay, the maximum pressure on which is about 3,700 pounds per square foot, which obtains when the tank is full of water.



The Chicago Bridge & Iron Co. were contractors for the iron work, which was completed in March 1895, water being admitted for the first time on the 23d of March.

The cost of the tower was as follows:—

Steel Standpipe, including girders and iron work	\$4,450 00
Brick Casing	2,807 00
Foundations	677 63
Total Cost	\$7,934 63

SOME FACTS CONCERNING DRAWING FOR ENGINEERS.

 BY FRANK ABORN, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read June 11, 1894.*]

SINCE accepting the invitation of your committee to read a paper on drawing, the idea has continued to grow upon me that I was "carrying coal to Newcastle." Skill in drawing is a prime factor in the engineer's equipment. It is in hourly requisition in his daily work. How can I tell him anything new concerning it?

These are the conditions that have confronted me in preparing this paper; and, because of them, I have chosen to discuss the beginnings rather than the ends of acquisition, feeling that constant users of drawing will more readily understand and take more interest in discussing a few facts concerning the process of learning than they might in anything I could say about its application.

In discussing this subject the great difficulty is to keep in sight the simple fact that drawing is purely a descriptive agent. This is the one fact, that, in this connection, should never be forgotten. Kept in view, profitable discussion is possible, and once finding lodgment in the learner's mind, the acquisition of skill in drawing is only slightly less certain and rapid than learning to walk or to talk.

Drawing is precisely analogous to verbal language, except in the scope of its application, but, within its own peculiar limits, it is much clearer and more concise. Drawings are only essays in lines, which have the advantage over written essays in that they require less time in execution and may be read at a glance even by the uninitiated. Drawing is the natural Volapük. Everything may be described in words; but certain classes of ideas, mostly those of form, may be more concisely as well as more completely expressed in lines. And to read verbal essays one must be familiar with the language in which they are written, while drawing may be read with the same facility regardless of nationality. These are important advantages, but the most important of all is the ease and rapidity with which drawing may be read. To realize how great this advantage is, it is only necessary to imagine oneself attempting to read the descriptions of two similar mechanical devices, one of which is in drawing and the other is in writing. Both are equally complete and exact, but what a difference in the time, strength and capability required to read and comprehend their respective meanings! The drawing may be read easily by most anyone, while to read the written description requires time, close attention, and, above all, a mental training of an unusually high order.

* Manuscript received June 26, 1895.—*Secretary, Ass'n of Eng. Socs.*

Looking at drawing from this standpoint, and regarding it as merely a means of expression, puts us on common ground; and now, if you will pardon me, I would like to remind you of something else that you are entirely familiar with, but which it is necessary to mention in order that I may put myself in complete touch with you: I refer to the application of drawing in practice. Let me call to your minds the part drawing plays in the development of any new engineering enterprise. First, there is the general conception of the way a given end is to be attained. Then comes a series of preliminary sketches, the chief function of which is to assist in crystallizing the thought. After this comes more precise drawing. Everything, at this point, is exactly placed. Relations of parts are determined, sizes are established and interferences are avoided. Nothing more can be done preparatory to actual construction except to lift the picture out of the working drawings, so far prepared, and by thus showing how the device will appear when completed, make it clear where changes may be made which will secure greater economy of space or improve the general appearance. The final set of drawings is now made, including as many illustrative, detail sketches as will reduce the chances for misunderstanding and the necessity for verbal explanation to a minimum.

Such procedures involve two kinds of drawing, one of which describes dimensions and the other expresses appearances. Both kinds of drawing are in constant requisition in all varieties of construction work. Final drawings of both kinds must be instrumental, otherwise they cannot be sufficiently exact. But preliminary sketching, the thought-requiring, thought-provoking and thought-developing drawing, is almost exclusively free-hand.

The well-rounded draughtsman, then, must have command of both. He must be able to describe form pictorially as well as in dimension and have the capacity to express himself promptly, clearly and concisely both instrumentally and free-hand. But such draughtsmen are rare. All can execute dimension drawings, while very few have full, ready command of pictorial expression.

In light of the fact that what are called mechanical draughtsmen are to be met with on every hand, while persons possessed of practical command of free-hand pictorial skill are rarely found, it would seem a hazardous statement to say that pictorial skill is the easier of attainment, or that it is primary to command of dimension drawing, but such are the facts. Free-hand, pictorial skill may be acquired in less time than any other form of drawing, and, being acquired, all other varieties of drawing are mastered with the least expenditure of time and effort. Indeed free-hand skill so prepares the way that, if mastered, orthographic projections, isometric, perspective and all the draughtsman's

arts are understood instantly they are presented. The reason for this, as well as the proof that it is so, will readily appear if inquiry is made into the cause of the present condition.

A very brief investigation will show that it is due to an illusion regarding pictorial drawing and the absence of illusion regarding dimension drawing. To comprehend the full force of this fact, to understand what a part it plays in hindering the acquisition of skill, and to appreciate how simple and straightforward both teaching and learning to draw will be, when illusion is dispelled, it will be only necessary to make some inquiry into how we see and determine what constitutes resemblance.

Seeing consists in recognizing the fact that similar optical sensations are derived from similar sources. One object is recognized to be a horse and another to be a man, because the optical sensation derived from each is similar to that we remember to have experienced before, and to have proven to have been derived from a horse or a man, as the case might be. So infallible is this rule, that all things are alike from which similar optical sensations are derived, that the thought of an exception has no natural excuse. But there is a very common exception to the rule, which is met in every picture that is seen. A picture is a picture of an object only when the optical sensation it gives rise to is similar to that to be derived from the object itself and there is nothing to suggest that there is any important difference between them. But there is a very radical difference, and failure to properly appreciate it is the prime cause of all the difficulty every one experiences in learning to draw. It causes effort to draw to be invariably misdirected. It insures, that, for a longer or shorter time, at the outset of learning, in each individual case, every thought, every observation and every act shall be from a wrong point of view and on entirely mistaken premises. And this, too, in the most unshakable confidence in the correctness of both, but more or less distrust of personal capability to execute.

Before intelligent effort is possible, all this must be changed. The beginner in drawing must be brought to doubt everything but his own power to learn. He must be brought to question his understanding of conditions and requirements and to doubt the truth of his premises: but not to lose faith in himself or in his powers to gain.

Whether the individual is learning dimension or pictorial drawing, in one particular, at least, does not matter. Progress in the attainment of skill in any direction is entirely dependent upon the dawn of intelligence, and this is impossible in the presence of illusion. With regard to the hand, the pencil, or the paper, or the slate, in the elementary stages, all that is required is that they shall be capable of making and taking marks that can be easily seen. The prime factor is intelligence. When any one comprehends that all drawing is descriptive, in the same sense

that writing is descriptive, the drawing of lines will be undertaken with a clear understanding of what their true function is. As the understanding becomes more fully developed, discrimination will become more and more acute and the demand will be created for finer and finer execution, which will induce the successful effort to devise ways and means of meeting it.

Ruskin has somewhere said to this effect: "To learn to draw, one must come to look at things with his natural eyes." That is to say, he must look at things not as objects, but as surfaces, as the child looks at the sky at night, seeing all the stars as so many sparks on a plane, rather than as so many distinct bodies and systems at varying distances from us. Every one does this in dimension drawing, but no one does it in pictorial drawing. If they did, present conditions would be the reverse of what they are, and every one would learn pictorial drawing without difficulty, and learning dimension drawing would be child's play to what it is now. For when any one perceives the dissimilarity between picture and object he will intelligently approach all delineative problems because his point of view can never be mistaken nor his aim ever be wrong or uncertain.

Much has been and still is said about "talent" in drawing, meaning thereby that there is a certain quality of mind necessary to its attainment. Whether all people may become true artists need not be discussed here; but that peculiar "talent" is required in the acquisition of practical skill in pictorial drawing, such as would admit of its being used as freely and readily as writing, has not the slightest foundation in fact. That such skill is not common proves nothing. Learning to draw is a question of state of mind and not of quality. Practical command is within the reach of every one. It may be speedily acquired by whoever will assume and maintain the proper point of view. Whether any one attains to art is dependent upon conditions similar to those which maintain in literature. The great question in drawing, as in writing, is place. Is the line in the place to most effectively express the idea? is no less an important question than is the sequence of sentences in writing and speaking. This way of looking at it simplifies every phase of drawing. Nothing could be more straightforward, but, unfortunately, few things are so generally misapprehended. To see how deep-rooted this misapprehension is it is only necessary to observe how loose, baseless and sentimental most of the talk is that is used in this connection. Advocates of drawing have a good deal to say about art, for instance, which is as much out of place in this connection as it would be to talk about art in literature in connection with learning to read before the ability to express one's self intelligibly in words has been established. There is a good deal of generalization indulged in to the

effect that learning to draw induces the exercise of all the cardinal virtues. Mere sentimental gush, which is belied by the lives of most of those who should be its chief exponents, who, so far as I know, are no more cleanly, orderly or moral than other people. Such ceaseless exaggeration does no good, but actually harm. It tends to bring into disrepute what in truth is a most hard-headed, practical tool, not only as a means of expression, but as a means of developing a broader and better command of the intellectual faculties. Such effervescence tends to belittle the subject itself; but there is another class of expressions in common use that are at least unfortunate in that while they are not exactly false they are not wholly true, and, if not actually misleading, they do not contribute to dispelling illusions nor the evidence of misdirected effort. For example, lines are commonly regarded as comparable with letters, and for this reason instruction in drawing uniformly begins with practice in line-making in some form, however it may be disguised. This is a mistake. Drawing is a language, it is true, and it is impossible to have any just conception of it except from this standpoint. But the statement so often met with that drawing is a language of which the straight and curved line are the alphabet, is utterly incorrect and misleading, notwithstanding it is the view held by Dr. Harris, Commissioner of Education, and many others.

Drawing is a natural language, like speaking, and has no alphabet. Letters are mere arbitrary symbols, fixed in their form, while lines are variable. Not subject to caprice, however, but changing both in form and character with every modification of the point of view, precisely as the form and construction of sentences change under similar circumstances. Even the shortest line, a point, is a full sentence. It is in every way equivalent to "It is here." It expresses a fact of position as completely and more concisely than could be done in words. A line of more than one point expresses position, direction and distance. It is, at least, the equivalent of "This is the direction and distance between two points." Whether a line is rough or smooth, straight or crooked, is secondary. Whether it is most effectively placed is primary. There are also other forms of expression in common use in this connection, which, though they do not actually beguile the mind, do not contribute to clarifying the intellectual atmosphere.

It is common to say that an object is drawn, meaning that it is delineated. But such a statement cannot be true. An object can no more be drawn than it can be written. As an object may be written about, so it may be drawn about. A picture may be drawn, but not an object. A picture can have but two dimensions, while every object must have three. It is also common to say that the object is looked at when it is drawn, but this, too, is incorrect. In drawing, the intelligently

directed eye does not direct itself *at* the object, but *beyond* or *by* it, a fact which will be further explained farther on.

As I understand it, the engineer values drawing exactly in proportion as he is able to use it supplementary to verbal language. He desires the ability first to express himself in it as freely as he does in writing. He cares no more what effect the general possession of such skill among the masses might have upon art than he does what effect a new invention is going to have on an older one. What he desires is command of a tool which will enable him to accomplish more with less effort. To this end, the established systems of teaching drawing have been proven totally inadequate. Their whole reliance is based upon doing or executing a certain number of prescribed things with a certain degree of precision. They are ponderous, stupid and inefficient.

That the average individual does not gain possession of this tool language by himself is plain. And that the teacher can only help him to do so in proportion as he himself understands the requirements of the case, and knows how to meet them, goes without saying. It is manifestly not enough that the individual goes through a given series of executions, for if it were, every grammar-school pupil would be able to draw anything. The simple use of drawing, as is now so general, with a view to securing greater efficiency by means of correlation, is also unproductive of proper understanding and is unproductive in the very large majority of cases. Drawing from objects most carefully selected, and with the assistance of criticisms from those who know, may fail for reasons which I shall explain farther on. A knowledge of perspective is everywhere proven to be inadequate. If it were not thus, every student of descriptive geometry would be an all-round draughtsman, and they are not. Modeling in clay will not develop a command of pictorial drawing; if it would, every modeler and carver would be a draughtsman in the best sense, and they are not.

So much is preliminary; but it has been necessary in order that common ground between us may be assured. The real facts which I most desire to make clear are so infinitesimal and yet so perfectly plain to be seen, that they are uniformly overlooked, as I overlooked them for many years, expecting to find something deep, intricate, or obscure. But so plain and simple are the steps in learning to draw that the only marvel is that they need even to be suggested. Yet so long a chase have they led me and so difficult do I find it to make myself understood that I have trespassed on both your time and your patience. But the rest is soon told.

Allow me at this point to remind you of a few simple, commonplace facts. The first of these facts is that nothing can be seen except it hide something else from view. For example, I could not be seen by you now

were it not for the fact that I prevent your seeing some of the wall behind me. If the button on my coat did not hide some of the coat it could not itself be seen. If my hand did not hide a part of my body it would not be visible. And if my thumb did not prevent some of my hand being seen by you it could not be known that I had a thumb.

If then you were to make a picture of me, at this time, you would not draw me but my silhouette. If you were to make a picture of the button on my coat you would not draw the button, but the shape that the button hides. To one this hidden shape would be almost if not quite a straight line, to another it would be an ellipse, while to still another it would be a circle, and no one would look *at* the button while describing it, but he would look *beyond* it. Likewise with my hand, in no case would it be drawn, but the shape that it hides; or, speaking more exactly, the base of the pyramid of rays of light reflected from the hand to the eye would be drawn.

It will be seen from this that the ability to draw is not dependent upon the possession of any modicum of knowledge, neither is it dependent upon any peculiar quality of brain, but it does depend upon the absence of all illusion and a clear, unclouded intelligence regarding requirements. In other words, learning to draw is dependent upon a state of mind. To get into this state of mind is the business of the learner, and to induce this state of mind is the duty of the teacher. It is not enough that this or that has been done, it is not enough to draw fine lines, make fine executions, nor to draw from the antique.

The acquisition of skill in drawing is precisely similar to all other processes of development. It is not unlike the development of an invention. It consists, first, in a struggle for comprehension. Nothing is polished or finished until it is fitted, nothing is fitted until it is located, and manufacture is not begun until everything else is done. Development and manufacture cannot be successfully carried on simultaneously in anything, particularly anything educational. Every drawing must be made for one of two purposes, it must be a means or a product or end. In proportion as it seeks to be both it fails in both. If a drawing is a means, it can have no value, if it is an end it is much for itself, or a part of something else, and has more or less value according to the condition of the market. Learning to draw is an educational or developing process, the drawing of every line is done with a view to an end which lies outside of the doing or the line. In the beginning stages it is a means of correcting the understanding of requirements, after that it becomes a means of improving the power of discrimination. Then it becomes a means of expressing ideas, and, finally, it is the means of emotional expression and culture. It is a perfectly direct highway, unmistakable as a turnpike when once seen, passing without deviation, from intelligence

to culture through the conscious exercise of power. Whether the aim or destination is power or culture, the ways and means are in nowise affected.

The first step in development is to dispel all allusion regarding the relation between picture and object. This is best done objectively, but it is a delicate operation. If it is done right the result is favorable, quiet and certain. I will not burden you with the details of a complete course as I would lay it out for children, but will suppose, if I may, that there were some of you who cannot draw pictorially, and that I wished to illustrate how you might be taught. I would choose some object that could be so placed that in some one respect there would be a marked case of foreshortening, bringing out the strongest possible contrast between the pictorial and actual relations of parts.

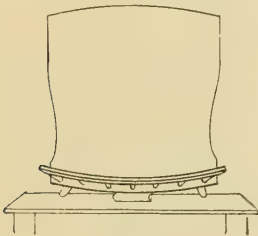


Fig. 1.

I might select a chair for the purpose, and place it where its back would be foreshortened, as shown in Fig. 1. The class being now instructed to draw something that would show how they see the chair from where they sit, the result would no doubt resemble Fig. 2. Each of these results would be an exact exposition of the state of mind regarding the requirements of drawing, of the individual who made it. And what the effect of making it may be depends upon how I, as the instructor, proceed. What I do, in this capacity, depends upon the purpose I have in view. If I desire an immediate result I criticise the execution and the condition and quality of the pencil and paper, as well as point out errors and suggest errors in the drawing. Learning to draw under such management will be exceedingly slow and very doubtful. If I wish to concentrate my forces, and bring out errors with effect, the number of different ways I might proceed depends upon my

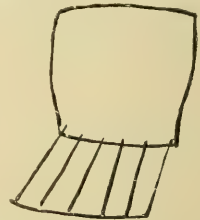


Fig. 2.

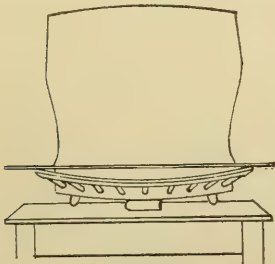


Fig. 3.

ingenuity. For instance, by laying a stick across the rail of the back of the chair, as shown in Fig. 3, and by thus calling attention to where it is seen, and making it clear that, because the stick is seen and should be drawn higher in the picture than the back of the chair-seat, makes it clear that the rail, itself, since it touches the stick should also be drawn higher than the back edge of the chair-seat. Or, the same end might be secured in a simpler way. It might be done by simply calling attention to the fact

that the spindles of the chair-back are seen below the rail while they have been described above it. It may be brought out, in this connection, that describing the spindles above rather than below the rail is a falsehood. But, however, it is done it is ineffective or rather insufficient. Objects may be described over and over again and there will remain a large number, if not a majority, who do not learn. If, however, my purpose is to come at the cause of error and make that clear, rather than to point out the error, I shall make use of the back-ground. In every case I shall ask him to show me what the misplaced part hides. This he will do instantly. He will then comprehend where it should have been placed and why he failed to place these. In the present case I should ask the pupil if he could see the whole of the top of the chair-seat. If he answered yes I should, by making chalk marks on the chair-seat that I would know to be hidden to him, bring him to see that he could not see the whole of it and what prevented. There is no one so dull of comprehension that he cannot comprehend this, and very presently any one will come to understand the cause of their errors and avoid them. They are, then, intelligent. But intelligence is not enough. Skill is what is wanted. The ability to describe what can be seen is only the entering wedge. Engineers do not draw for fun. It is business with them and business rarely if ever requires them to describe what is present and visible. Such things are their own best exponent, drawing about them is not called for. What the engineer requires is power, which is the ability to describe absent objects or things that exist only in his imagination.

As soon, then, as intelligence is established, the exercise of the imaginative faculties should be taken up and vigorously pursued; beginning with the description of present objects from imaginary and inaccessible points of view and proceeding to pure invention.

But approximate work will not do. The discriminating sense must now be developed. The subject-matter in this case must be such as will demand the closest observation of relations, at the same time it must have, in itself, such an interest for the student as to enlist and hold his constant and undivided endeavor. Such a subject for study is the human head from life. Nothing else is so fascinating, so exciting, so instructive or more cultivating.

In all work, when rightly aimed, there is a natural constantly increasing demand for better execution. At the proper time, in the place and in the proper degree, technique will have its proper attention. But it cannot economically precede intelligence nor take the place of power.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Motive Powers AND THEIR PRACTICAL SELECTION. By Reginal Bolton.
London and New York: Longmans, Green & Co. 257 pages.

The author has set himself the task of compiling in convenient form the data and formulæ which bear upon the selection of a motive power suited to the conditions of any particular case, and of arranging these in convenient shape for reference by engineers or ready comprehension by the non-technical. The work has been well done, and the only wonder is that it has not been done before, as it must prove of great value and economy to those contemplating the use of power.

The author first discusses the primary considerations as to the various sources of motive power and their availability, and then devotes separate chapters to manual, animal, wind, water and steam power, as well as to electricity and to gas engines. For each of these rules are given, which permit of calculating the size of machine required, the cost of working and the relative economy under various conditions. There are a number of valuable tables, showing how the comparisons may be made, and the results are given both in pounds sterling and in dollars.

NOTE.—This notice is contributed by the Western Society of Engineers, to which the author has kindly sent a copy of his book.

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XIV.

JANUARY, 1895.

No. 1.

PROCEEDINGS.

Engineers' Club of St. Louis.

409TH MEETING, JANUARY 2, 1895.—President Russell called the Club to order at 8.05 P.M., at 1600 Lucas Place. Twenty-two members and five visitors were present.

The minutes of the 407th and 408th meetings were read and approved. The Executive Committee reported the doings of its 174th, 175th and 177th meetings, announcing that the dues for 1895 had been fixed at \$8 for resident members and \$5 for non-residents. The Committee had approved the applications for membership of F. E. Bausch, S. E. Johannessen, W. A. Layman and A. W. Morrell, and these gentlemen were then ballotted for and elected. An application for membership was announced from Mr. William H. Moore, surveyor in the office of the street commissioner.

Col. E. D. Meier then read a paper on "Chimneys and Chimney Drafts." The paper had been printed, and copies were given to those present. The subject was considered with special reference to modern boiler practice and American coals. Computations of stack capacity usually assume the chimney gases to be of the same specific gravity as air. This assumption is erroneous, for, when combustion is complete, the gases are really a mixture of carbonic acid gas, nitrogen, and steam; the proportions varying with different coals. As these require different amounts of air, the varying weights of the gases of combustion cause a difference in the draft power of the same chimney. It is rare that just the proper amount of air is admitted, and there is a loss when the amount is too little or too great. Very often there is a surplus, reaching sometimes as high as 100 per cent. Tables were presented, showing these facts clearly for five well-known coals: Anthracite, New River, Youghiogheny, Mount Olive, and Collinsville. Computations were made, showing how the capacity of a chimney could be increased much beyond the normal by raising the temperature of the gases, the result always being accompanied by a corresponding loss in efficiency. It was shown that the same capacity could be obtained without loss of efficiency by increasing the height of the chimney. A table was given, showing the changes effected in the capacity of a given chimney by varying the temperatures of the gases; also the change of height necessary while maintaining a constant temperature. Another table showed the effect of different coals on the velocity of the gases, and on the areas of chimneys, the velocity being kept constant. The chimney formulæ of Smith, Kent, and Gale, and the experi-

ments of de Kinder, were discussed. A table was given, showing appropriate heights and areas of chimneys for powers from 75 to 3100 horse-power, assuming seven pounds of water evaporation per pound of coal, and five pounds of coal per horse-power per hour. The effect of the length of the flue leading to the chimney was also discussed. It was shown that where a number of boilers are to be connected to the same stack, its dimensions can be reduced proportionately (as compared with the first few boilers), as they would never all be fired at the same time.

The paper was discussed by Messrs. Hermann, Ockerson, Bryan, Holman, and Kinealy. It was shown that large chimneys almost always overrun their capacity as computed by the best formulæ. It was believed that the table presented by Col. Meier, while justifying the working of chimneys to larger capacities than heretofore deemed advisable, was still conservative, and that in emergencies the chimneys could be worked much beyond the ratings given.

Mr. Russell explained an ingenious method which had recently been resorted to at the inlet tower of the new water works at the Chain of Rocks for cutting off the timber of the old coffer-dam under water. Adjourned.

WILLIAM H. BRYAN, *Secretary*.

410TH MEETING, JANUARY 16, 1895.—The Club was called to order at 8.10 P.M., by Vice-President Ockerson, at 1600 Lucas Place. Twenty-one members and seven visitors present. The minutes of the 409th meeting were read and approved. The Executive Committee reported the doings of its 178th, 179th and 180th meetings, announcing the resignations of J. C. Simpson and D. C. Humphreys, and approving the application for membership of W. H. Moore. The Committee submitted the following program of papers and addresses for the year 1895:

- January 2d—Chimney Draft, E. D. Meier.
- January 16th—River Surveys by the Transit and Stadia, J. L. Van Ornum.
- February 6th—Discussion of B. L. Crosby's paper on the St. Louis Extension of the St. L., K. & N. W. R. R. A System of Removing Organisms from Liquids. J. H. Curtis.
- February 20th—The Mechanics of Soaring Flight (a translation), E. D. Meier.
- March 6th—Timber Physics, J. B. Johnson.
- March 20th—European Engineering Schools, W. S. Chaplin.
- April 3d—Methods of Determining the Heating Power of Coals, J. H. Kinealy.
- April 17th—Vitrified Brick for Street Paving, H. A. Wheeler.
- May 1st—The Design of the Train House of the New Union Station at St. Louis, Geo. H. Pegram.
- May 15th—An Experimental Investigation of the Three Moment Theorem, M. A. Howe.
- June 5th—Water Towers at Laredo, Tex., and St. Charles, Mo., Edw. Flad.
- September 18th—Maintenance of Bridges, C. Gayler.
- October 2d—The Continuous Rail in Street Railway Service, R. McCulloch.
- October 16th—Sewerage of Indianapolis, C. C. Brown.
- November 6th—Chimneys and Chimney Draft, W. E. Worthen.
- November 20th—Report of Committee on Smoke Prevention.
- December 4th—Annual Meeting.
- December 18th—Installation of Officers—Address of Retiring President.

The Executive Committee recommended to the Club that Mr. Henry Flad be elected an honorary member.

On balloting, Mr. Flad was unanimously elected an honorary member and Mr. W. H. Moore a member.

The Secretary read a communication from Col. E. D. Meier, Secretary of the American Boiler Manufacturers' Association, asking the co-operation of the Club in a movement to secure legislative enactment in the direction of State Boiler inspection and the licensing of engineers. On vote, it was ordered that the Chair

appoint a committee of three to consider the matter, and to meet a committee of the American Boiler Manufacturers' Association, the Committee to have no authority to bind the Club in any way, but to report to the Club the result of its conferences and conclusions. The Chair appointed on this committee Messrs. Holman, Bryan and Perkins.

Mr. J. L. Van Ornum, of the Western Society of Engineers, then read a paper on 'River Surveys by the Transit and Stadia,' describing a method of surveying the smaller navigable streams by the use of the stadia alone for all topographical work, as well as for the location of soundings, thus dispensing with both the triangulation system and the angular methods of locating soundings.

The plan was particularly recommended where speed, low first cost and reasonable accuracy were desired, rather than extreme precision. The discussion was quite full, and was participated in by Messrs. Moore, Bouton, Ockerson, Butler, Jolley and Crosby. Adjourned.

WILLIAM H. BRYAN, *Secretary*.

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., JANUARY 7, 1895.—The twelfth annual meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Fifteen members and one visitor were present. Vice-President Estabrook presided. The minutes of the previous meeting were read and approved. The Librarian reported verbally on a method of securing back numbers of the *Transactions of the American Society of Civil Engineers*, and the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. The report was accepted. Mr. Morris gave the Society an outline of recent work of the Board of Managers of the Association of Engineering Societies. The discussion of the Minnesota State Survey and other matters incidental thereto was entered into at considerable length, and the committee thereon was granted another month's time to make a report. The gift of various back numbers of the *Railroad Gazette* and other periodicals was accepted from the "Omaha" Railway Company and ordered bound. The following annual reports were read and accepted:

REPORT OF THE SECRETARY.

ST. PAUL, MINN., January 7, 1894.

To the President of the Civil Engineers' Society of St. Paul.

SIR:—In accordance with the usual custom I present the Society statistics for 1894.

Eight regular meetings have been held, with an average attendance of thirteen members and three visitors. The subjects which were discussed for the entertainment of the Society are given below, with dates. Most of them were informally presented, but the papers of Mr. Johnson, Mr. Claussen and Mr. Woodman were carefully prepared. Mr. Woodman's paper on Transition Curves will shortly appear in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

February 5th, "Construction of Dam at St. Anthony Falls," by Mr. C. A. Hunt.
 "Failure of a Portion of Westminster Street Tunnel," by Mr. K. E. Hilgard.
 "Diagram for Weir Measurements," by Mr. A. Münster.

March 5th, "Coal Docks and Coal Handling Plants," by Mr. C. J. A. Morris.

April 2d, "The Supply of Water Obtained from Government Reservoirs in Minnesota," by Mr. Archibald Johnson.

May 7th, "Requirements of a Municipal Electric Light Plant Installation," by Mr. O. L. Claussen.

October 1st, "Transition Curves," by Mr. Edwin E. Woodman.

November 5th, "The Minnesota Geological and Topographical Survey," by Prof. W. R. Hoag, of Minneapolis.

December 3d, "Riparian Ownership of Lands Bordering on Lakes and Rivers," by Mr. J. H. Armstrong.

On October 20th, ten members of the Society attended a joint excursion to Sault Ste. Marie, arranged by President Cappelen of the Engineers' Club of Minneapolis. Two days were spent in examining the new locks on both sides of the river and other improvements in the vicinity.

MEMBERSHIP STATEMENT.

January 1, 1894	54	Resident members	39
Increase in membership	3	Non-resident members	18
Present Membership	57		57

Respectfully submitted,

C. L. ANNAN, *Secretary.*

REPORT OF THE TREASURER.

President Civil Engineers' Society of St. Paul.

SIR:—I submit herewith my report as Treasurer of the Society for the year ending December 31, 1894.

RECEIPTS.

Cash on hand, January 1, 1894	\$ 1 74
Collections during year	239 27
	<hr/> \$241 01

DISBURSEMENTS.

Stationery and miscellaneous accounts	\$ 14 10
Dinner at Commercial Club	17 00
Room rent	10 00
Library: Subscription to periodicals, etc.	78 96
Assessments, Association Engineering Societies	77 65
Cash on hand	43 30
	<hr/> \$241 01

Respectfully submitted,

A. O. POWELL, *Treasurer.*

REPORT OF THE LIBRARIAN.

To the President of the Civil Engineers' Society of St. Paul.

SIR:—The total number of volumes in the library at the end of the year 1894 was 352, including engineering periodicals for the past year. Of this number, 255 are bound volumes and 97 unbound, including the *Annales des Ponts et Chaussées* for the years 1891, 1892, 1893 and 1894, to the number of 48 volumes. The Society now subscribes for, or receives free, the following engineering periodicals: *Transactions of the American Society of Civil Engineers*; *Transactions of the American Society of Mechanical Engineers*; *JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCI-*

TIES; Journal of the New England Water Works Association; Engineering; Engineering News; Engineering Record; Proceedings of the Western Railway Club; Engineering and Mining Journal; Annales des Ponts et Chaussées.

* Respectfully,

A. MÜNSTER, *Librarian.*

Officers for the coming year were elected as follows:

President, H. E. STEVENS.

Vice-President, K. E. HILGARD,

Secretary, C. L. ANNAN.

Treasurer, A. O. POWELL.

Librarian, A. MÜNSTER.

Representative on Board of Managers for the Association of Engineering Societies,
EDWIN E. WOODMAN.

A vote of appreciative recognition of past services was given to Mr. Morris and other retiring officers. President Stevens appointed Mr. Rundlett auditor of accounts for 1894, and named Mr. Woodman, Mr. Powell and Mr. Armstrong as members of the Examining Board. The Treasurer was authorized to make the usual arrangements for the care of the library.

C. L. ANNAN, *Secretary.*

Civil Engineers' Club of Cleveland.

ROOMS OF THE ELECTRIC CLUB OF CLEVELAND, O., JANUARY 8, 1895.—The meeting was called to order at 7.55 P.M. by the President. Thirty-five members and visitors were present. The minutes of the meeting of December 11, 1894, were read and approved. The report of the Executive Board was read and approved.

Under the head of miscellaneous business, President Swasey brought up the question of returning to our former quarters in Case Library, stating that Mr. Rawson and he had learned that it was expected by the library people that we do so. He also stated that he had written a letter to the Librarian, asking when we might expect to resume our pleasant relationship, and had received a reply to the effect that the library would be ready on or before the 20th of January. On the request of the President, Mr. Rawson stated that, while acting not officially, he had accidentally discovered that we were expected to return, and at the former terms, that he had brought the matter to the attention of the President, and that the above result had been reached by further inquiry. Mr. Porter stated that he had learned that books and papers could be consulted in about ten days. Mr. Searles brought up the matter of entrance, and stated that he understood that entrance could now be gained to quarters only through the library proper. He suggested that inquiries be made as to whether we were likely to be embarrassed as to hours of meeting or of adjournment. Remarks were also offered by Messrs. Warner, Herman and Reid. Mr. Rawson moved that the matter be referred to the Executive Board with power to act. Seconded by Mr. Searles, and passed.

Mr. Searles submitted amendments to the Constitution, as follows:

ASSOCIATION OF ENGINEERING SOCIETIES.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

Amendments to Constitution, proposed January 8, 1895.

ARTICLE 5.—DUES.

Section 1.—Strike out "Five" and substitute "Ten."

Section 2.—Strike out "Eight" and substitute "Ten."

Strike out "Six" and substitute "Eight."

Strike out "Four" and substitute "Five."

ARTICLE 9.—AMENDMENTS.

Section 2.—Strike out all after the word "which," and insert "shall go into effect on the first day of March next following the date of adoption."

We, the undersigned active members of the Civil Engineers' Club of Cleveland, present the above Amendments, and move their adoption.

JAMES RITCHIE,
WM. H. SEARLES,
(Signed), N. P. BOWLER,
W. R. WARNER.

Mr. Searles moved to amend Amendments by considering the three various sections separately. Seconded and passed.

Mr. Porter moved that we proceed to ballot for the Nominating Committee, and the nominations were placed upon the blackboard. The President appointed Messrs. Palmer and Brown tellers, who announced the result as follows: Nominating Committee, Messrs. Porter, Warner, Searles, Bartol and Gobeille.

The paper of the evening on "Pavements of Cleveland Compared with Those of Other Cities" by James Ritchie, C. E., was then read by the Secretary, pro tem. A discussion on the paper by Messrs. Rawson, Culley, Claffen, Swasey and Porter, and Colonel Smith followed.

Meeting adjourned at 10.30 P.M.

A. LINCOLN HYDE, *Sec. pro. tem.*

The Montana Society of Civil Engineers.

EIGHTH ANNUAL MEETING, JANUARY 12, 1895.—The meeting was called to order by President Haven, in the Board of Trade Rooms, Granite Block, Helena, Mont., at 11 A.M.

There were present, Messrs. Keerl, Goodale, Page, Ryon, McNeill, Wheeler, Gutelius, Haven, Cumming, Hovey, McDonald, Scheetz, Smith, Carroll and McRae.

Applications for membership were read from Charles Maurice Allen, Charles Henry Palmer, Daniel Perrin Mumbrie, Maurice S. Parker and Charles Wright Mead.

Votes on the amendments to the By-Laws were then canvassed. Mr. Gutelius and Mr. Wheeler were appointed tellers. There were twenty-nine ballots cast on the first proposition, all "Yes." On the second proposition, twenty-eight "Yes" and one "No." On the third proposition, twenty-seven "Yes" and two "No."

There being a majority of votes cast for all the proposed amendments, they were declared adopted by the Society.

It was voted that the By-Laws regarding the counting of ballots for membership be suspended, and that those ballots be counted. Mr. Wheeler and Mr. Gut-

lius were appointed tellers. They announced the result and the President declared that the Society had elected the following persons members of the Society: Paul S. A. Bickel, James Breen, Charles Alexander Dewar, Francis Webster Blackford, Albert Alton Morris and Clayton Miller Thorp. Thereupon Messrs. Bickel, Dewar, Morris, and Thorp being present, took their seats.

Mr. Page and Mr. McNeill, appointed tellers to count the ballots for officers, announced the result, and the President declared that the Society had unanimously elected the following persons as officers of the Society for the year 1895: President, James S. Keerl; 1st Vice-President, Augustus M. Ryon; 2d Vice-President, James M. Page; Secretary and Librarian, Forrest J. Smith; Treasurer, A. S. Hovey; Trustee for three years, Charles W. Goodale; Member of the Board of Managers of the Association of Engineering Societies, James S. Keerl.

The President read the report of the Secretary as follows:

Helena, Mont., January 12, 1895.

RECEIPTS.

For entrance fees	\$ 50 00
" dues for the year 1893	91 00
" " " " 1894	173 00
" " " " 1895	63 95
" miscellaneous receipts	12 00
Total	\$389 95

EXPENDITURES.

Paid to A. S. Hovey, Treasurer, as per receipts herewith submitted, No. 1 to 17 inclusive	\$389 95
Totals	\$389 95

There is due from members for the year 1893	\$ 30 00
For the year 1894	103 00
Amount overpaid by members and credited on the account for 1895	22 95

G. O. Foss, *Secretary.*

Helena, Mont., January 12, 1895.

Statement from the books of the Secretary, showing the expenditure of the Society during the year ending to-day. For details see warrants No. 99 to No. 131 in the hands of the Treasurer (No. 113 cancelled and 130 not presented for payment).

For typewriting and report of meetings	\$ 27 35
" postage, expenses of officers	29 50
" sundry expenses, annual meeting, 1894	5 25
" publishing list of members	17 50
" binding newspapers, etc.	9 50
" extra bill of Associated Society	5 90
" printing notices, reports, letter-heads	98 20
" drawings for Journal, accompanying paper	8 00
" stationery for offices	11 55
" the JOURNAL OF ASSOCIATED SOCIETIES	134 50
Total	\$347 25

G. O. Foss, *Secretary.*

per W. A. HAVEN.

It was moved and seconded that the report and statement of the Secretary be accepted and referred to the Trustees. It was so voted.

It was voted to pay the expenses of the Annual Meeting of 1895 from the funds of the Society.

The report of the Treasurer was then read as follows :

January 13, 1894, by balance cash on hand	\$ 26 36
By amounts received at sundry times from G. O. Foss, Secretary, as per receipts on file in his office	389 95
Total	\$416 81

EXPENDITURES.

Amount paid as per warrants herewith submitted, Nos. 99 to 131 inclusive, excepting No. 113 cancelled, and No. 130 not yet presented for payment	\$347 25
Paid to H. J. Horn, Jr., per order of the President	2 00
Total expenditures	\$349 25
January 12, 1895, balance on hand	67 56
A. S. Hovey, Treasurer	\$416 81

No further business offering, the Society thereupon took a recess until 2 P.M.

2 P.M.

The first order of business was the installation of the new officers as announced in the forenoon.

The retiring President read his address as follows :

GENTLEMEN :—In retiring from the office of President, I congratulate you all upon the recent healthy growth of our Montana Society, not only in the number of its members, but in their professional standing. In looking over our list of members and referring to a catalogue of the members of the American Society of Civil Engineers, I find that 25 per cent. of our members are also members of that Society and that about one half of the remainder are qualified, both by age, experience and professional attainments for membership in that Society.

When our list of members was printed, February 12, 1894, the Society was composed of two honorary members (one of whom was also a member), seven associate members and forty-one members. During the year no change has been made in the list of honorary or associate members. One member living in Minnesota has withdrawn. Thirteen new members have been elected, making the total number of members at the present time fifty-three, and to-day the applications of five more persons for membership have been read.

The reports of the Secretary and Treasurer, which have been read to you, show that the Society is in a healthy financial condition. The renewed interest in the Society manifested by our members, and the desire for membership expressed by engineers, surveyors and others in all parts of the State, are due, I think, to the fact that our Society has taken an active part in movements for developing the resources of our State in a practical, scientific and economical manner, and has thus acquainted the people of the existence of our Society and of our ability and readiness to grapple with the problems that must be solved by our people. I will quote from a

letter which I have just received from one of your former presidents, congratulating us upon our present prosperity. He says: "The only way for civil engineers to advance is to make themselves felt, and there is no better way than by their united strength *in organization* and in taking up the questions in which their existence is concerned."

We now have before the Society two matters of vital importance, not only to ourselves, but to the whole State of Montana, viz., (1) "the measurement and appropriation of water," and (2) changes in the Statutes of Montana in the interest of a better system of location, construction and repairs for highways and highway bridges, with a view of reducing taxes and at the same time of obtaining better results in the expenditure of the road tax which now amounts to over \$200,000 per annum in our State. Both of these matters will come before you to-day for your free discussion and final action.

The report of the Secretary shows an unusually large expenditure for printing, postage, and other expenses. This was incurred because the Society voted at its regular meetings, in November and December, to print a large number of the reports of the Committee on Water, and also that on County Surveyor and Road Laws, and to send copies not only to each member of the Society, but to the newspapers, members of the Legislature, County Commissioners, and other public men throughout the State, in order to enlist their support of the measures which we propose. I think it was money well expended, and for the benefit of the Society.

In the younger years of the Society, and up to the present time, we have had to avail ourselves of the charity of some of the members who have allowed us to occupy their offices, not only for our monthly meetings, but for the storage of our books and papers and for the work-room of our Society. My experience during the last three months as Acting Secretary as well as President, has convinced me that the Society should now have a room of its own, where it may have not only the desk, but book-cases for the rapidly-growing library, to which members can have ready access, and where they can read the current engineering literature and our many valuable books of reference. I recommend that, at the meeting to-day, a committee be appointed to secure permanent quarters for the Society, where its regular monthly meetings may be held.

The present Constitution and By-Laws seem to me to be defective. For instance, during the past year your Secretary has been absent from the State three-quarters of the time, and yet there appears to be no power, either in the Society itself or in any of the officers, to appoint a secretary *pro tem*.

During the absence of Mr. Foss, the duties of the Secretary were performed in a creditable manner by Mr. Cumming while he was in the city; but in Mr. Cumming's absence during October and November, I assumed the office of Secretary by virtue of the article of the Constitution, defining the duties of the President, viz., "He shall exercise all the powers and prerogatives appertaining to his office." In similar societies, the President is the executive officer, and it is his duty to see that the business of the society does not suffer by reason of the absence of any officer.

You have a board of three trustees—this seems a misnomer, as there is nothing whatever they hold in trust. I recommend that the Constitution and By-Laws be changed, so that in place of the trustees three directors may be elected, and that they, together with the President and Secretary, shall constitute a board of direction, who shall have full control of the affairs of the Society, with power to fill all vacancies in the elective offices, which may occur from any cause, until the Society can elect officers in the regular way.

During the last sixty days I have had considerable correspondence with the Chairman and Secretary of the Board of Management of the Association of Engineering Societies, regarding the policy of the Association in several matters. The member of the Board of Management, representing our Society, handed me the reports of the Secretary and letters from him and the chairman, and a list of ten questions to be voted upon, asking my advice thereon. As most of these questions referred to the financial situation, and thereby affected the treasury of your Society, and the pockets of each one of our members, I referred the matter to our Trustees, who directed me to instruct our member how to vote upon the several propositions. As there was a considerable difference between the views of our member of the Board of Management and the Trustees, I think it would be well if our Society should appoint a committee to investigate this matter and report the facts to the Society. All the papers relating to this subject are open to inspection, and it seems to me very important that our representative, when in doubt how to vote on any matter before the Association, should have a board of directors with whom he may consult at any time.

Our meeting in Butte, in October, was productive of good results to the Society, though uncontrollable circumstances prevented as large an attendance as we hoped to have. I hope that this feature of our Society may be continued.

I congratulate the non-resident members present at this meeting upon the fact that they reside along the line of the Northern Pacific Railroad, whose enlightened management recognizes that a meeting of such a representative body of men as the Montana Society of Civil Engineers contributes much to the material development of the State, and thereby to an increase of business for its lines, and I am sorry that it has no direct line between Butte and Helena.

Thanking you all for your ready aid in my efforts to promote the welfare of the Society during the two and a half years of my presidency, I take pleasure in introducing to you your new President, Mr. James S. Keerl, of Helena.

Mr. Keerl then made a short address, as follows:

GENTLEMEN:—I wish to relieve at once any apprehension under which you may be laboring, due to the suggestion of our retiring President that I should follow him with an inaugural address, for it is far from my intention to afflict you in this manner at this time. If I comply with our By-Laws, I shall try your patience sufficiently, a year hence, by the annual address therein prescribed.

It is scarcely necessary for me to assure you of my high appreciation of the honor you have conferred upon me by electing me your President for the ensuing year.

Under the very able management of our retiring President, our Society has advanced to a commanding and respected position in the estimation of the public, and I trust that I may, with your assistance, maintain its dignity and utility, and be in a measure at least, instrumental in forwarding its interests and those of the profession it represents. In a new State like Montana, a society of engineers has a wide and most interesting field for the exercise of the professional attainments of its members. Where we find existing faulty legislation affecting technical matters, the responsibility is upon us to use our best efforts to secure desirable corrections. The need of new legislation upon subjects of an engineering character should excite our deep interest, and we should use our best endeavors for the enactment of such laws which, while assuring the best interest of the State, will reflect credit upon us as engineers both patriotically and professionally.

Much earnest work has been done by some of you on these lines during the

past year, and, as a result, two committees will report to you, recommending Acts for presentation to our Legislature now in session. I bespeak for them your careful consideration and your best efforts to secure their passage after they have been duly received and approved by you.

Mr. Keerl then took the chair.

The report on water was then taken up and the Secretary read an Act establishing a standard for measurement for water, defining the equivalent of a miner's inch and repealing Section 1262, Division 5, of the Compiled Statutes of the State of Montana :

Be it enacted by the Legislative Assembly of the State of Montana :

Sec. 1. Hereafter a cubic foot of water per second of time shall be the legal standard for the measurement of water in this State.

Sec. 2. Where water rights expressed in miner's inches have been granted, one hundred miner's inches shall be considered equivalent to a flow of two and one half cubic feet per second ; two hundred miner's inches shall be considered equivalent to a flow of five cubic feet per second, and this proportion shall be observed in determining the equivalent flow represented by any number of miner's inches.

Sec. 3. Section 1262, Division 5, of the Compiled Statutes of the State of Montana, and any laws in conflict with this Act, are hereby repealed.

THE PRESIDENT : This report of Professor Ryon's is a very thorough one and certainly reflects great credit on the Society ; and while it is quite lengthy and full of formulas, it might be well, for the benefit of the members present, to have the "conclusions" read.

The Secretary then read the "conclusions."

Mr. Haven moved an amendment, to define, in the Act, for the information of placer miners, ranchmen and the "Old Timers," the quantity of water, in gallons, that is contained in a cubic foot. Professor Ryon seconded the amendment. The Act was then discussed at great length by Messrs. Page, Ryon, Keerl, Haven, Carroll, Goodale and Scheetz. The amendment was then adopted, viz.: to insert in line 2, after the word "foot," the following, "or 7.48052 gallons ;" after "feet," in line 7, "or 18.7013 gallons ;" after "feet," in line 10, "or 37.4026 gallons." The report and Act were then unanimously adopted as embodying the views of the Society, and it was voted that a committee of five be appointed to see that they be introduced in the Legislature, and to urge its passage. Messrs. Ryon, Cumming, Carroll, Scheetz and Tappan were appointed members of this committee.

The chairman of the committee on the memorial of our former president, Col. W. W. DeLacy, reported that it had nearly completed its labors and would submit the memorial to the Society at the monthly meeting in February.

The report of the Committee on County Surveyors and Road Laws was called for.

Mr. HAVEN : The committee sent to me, December 20th, one copy of its report with a proposed Bill. I immediately had 150 copies printed, and mailed a copy to every member of the Society and to county commissioners and others interested in good roads all over the State, requesting them to send me in writing their suggestions for alterations or amendments. By the middle of this week about a dozen of these had come in, and I called a meeting of the committee, who met here yesterday morning and so amended the Bill as to meet the suggestions received. At 10 o'clock this forenoon they handed me seven pages of closely-written manuscript. At 2 P.M. I received 100 printed copies of the report which Mr. McNeill, the chairman, will now present to you. You will find this different in many respects from the one sent you December 22d.

Mr. McNeill then explained what was sought to be accomplished, viz., to place the entire charge of the laying-out, construction and repairs of all county roads and bridges in the County Surveyor, who should be held responsible by the County Commissioners for the condition of the roads at all times and be made by law a member of all boards of "road viewers;" the County Surveyor to make and see to the execution of all contracts about roads and bridges, and to take the place of the present "road supervisors;" all road taxes to be paid in cash instead of being worked out, and thus, by expending the annual road tax in a systematic manner, to eventually reduce taxation and apply the tax in an economical manner and make a beginning of good roads in all the valleys and mountain passes of Montana.

In order to bring the whole matter before the meeting, both reports, that of December 22d and that of to-day, were then read by the Secretary. A long discussion was then had, all the members present taking part in it, as well as members of the Legislature, and County Commissioners, Mr. F. H. Ray, who represented the "Wheelmen," and surveyors not members of the Society. Questions of the constitutionality of the Act were discussed in an able manner by the engineers and "old-timers."

At six o'clock the meeting took a recess for dinner until half past seven. In the evening session the discussion was resumed. About thirty visitors were present, mostly men interested in our Road Law, among them two of the Commissioners of Lewis and Clarke County, several lawyers, judges and members of the Legislature. Questions of grades and highways, ditches, bridges, contracts for construction and repairs, and specifications were discussed. All the visitors heartily endorsed the general object of the Society, and hoped it would be able to overcome all the objections raised to the present proposed bill. They assured the Society of their hearty co-operation.

It was finally voted that the reports be referred back to the Committee, Mr. Cumming being substituted for Mr. Baker, who was not present. The Committee was instructed to employ legal advice and to report to an adjourned meeting of the Society on Monday evening.

The thanks of the Society were voted to Messrs. Wheaton and Muth, County Commissioners and to Judge O'Bannon for their advice and suggestions during the evening.

The Secretary was instructed to send a letter to the General Manager of the Northern Pacific Railway Company, through A. D. Edgar, General Agent, thanking him for his courtesy in granting to all of our members residing along its lines transportation to and from Helena.

It was voted that ballots upon the applications for membership, read at the morning session, should be sent out, to be canvassed at the next regular meeting.

Mr. Goodale.—For several months Mr. Haven has not only filled the office of President, but has acted as Secretary in the absence of that official, and I think the thanks of the Society should be given to him. It was so ordered.

Mr. Haven.—I have letters from Mr. Trautwine, Secretary of the Association of Engineering Societies, and from engineers of other societies ranging all the way from Boston to Tacoma and San Francisco, congratulating the Society upon its growth. I do not think it is due to me but to the action of the Society themselves in taking hold of practical matters of interest to the State.

Mr. McRae.—I move that a vote of thanks be given to Professor Ryon for the able manner in which he has treated the question of the Measurement of Water. He has been at a great deal of labor and possibly expense to himself, and I think he has done his work exceptionally well.

A vote of thanks was given to Professor Ryon.

The Society then, at 10.30 P.M., adjourned until Monday evening, when the members held a social function lasting until about midnight.

JANUARY 14TH.

The meeting was called to order by the President at 8 o'clock.

The Committee on County Surveyor and Road Laws reported that it had been at work since the adjournment on Saturday evening ; that it had taken legal advice and had consulted with Mr. F. H. Ray and with one of the Commissioners of Lewis and Clark County.

On motion of Mr. Haven it was unanimously ordered that the thanks of the Society be extended to Messrs. McNeill and Gutelius, who had been almost constantly at work since Friday morning, in order that they might prepare their report in time for this meeting, and who would have to remain in Helena one or two days after the close of the meeting, and that their expenses be paid from the funds of the Society.

A vote of thanks was given to Mr. Goodale for his efforts in Butte in increasing the membership of the Society.

The suggestions contained in the address of the retiring President were referred to a committee of one. The President subsequently appointed Mr. Goodale as this committee.

The Secretary was instructed to convey to the officers of the Board of Trade the thanks of the Society for the use of their rooms during the annual meeting ; also to Mr. Gardiner for his active co-operation and for his valuable legal advice in preparing the Acts and Bills for the Legislature.

The County Surveyor Bill was then read. A few minor changes were made and the Bill, as amended, was adopted for submission to the Legislature with the Society's approval.

The Road Law, as reported by the committee, was then read. It was discussed, section by section, and some amendments were made. Finally, it was unanimously adopted as embodying the sense of the Society as to what the Montana Road Law should be.

It was then voted that the committee be instructed to supervise the preparation of three typewritten copies of the proposed Act, in proper shape for presentation to the Legislature ; one copy thereof to be placed, with the County Surveyor Bill, in the library of the Society.

It was voted that a committee of five be appointed to present both bills to the Legislature and to watch over them until their final passage. (The President appointed Messrs. McNeill, Cumming, Harper, Gutelius and Dewar.)

A full stenographic report of the meetings, covering forty-six typewritten pages, is on file with the Secretary.

At 11 o'clock the meeting adjourned.

F. J. SMITH, *Secretary.*

Boston Society of Civil Engineers.

JANUARY 23, 1895.—A Regular Meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield Street, Boston, at 7.45 o'clock P.M. President William E. McClintock in the chair. 121 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Albert S. Cheever and James W. Rollins, Jr., were elected members of the Society.

On motion of Mr. FitzGerald it was voted to choose by nomination from the floor a committee of three, to report at this meeting the names of five members to serve as a committee to nominate officers. Messrs. Fred. Brooks, Henry Manley and John R. Freeman were chosen as the committee. Later in the meeting this committee reported the names of Desmond FitzGerald, A. E. Burton, R. A. Hale, F. W. Hodgdon and F. C. Coffin, and on motion these gentlemen were elected the committee to nominate officers for the ensuing year.

Mr. Henry Manley was appointed a committee with full powers to make the necessary arrangement for the annual dinner of the Society, and the sum of \$50.00 was appropriated for the incidental expenses of the dinner.

The President announced the deaths of Phineas Ball and Lincoln C. Heywood, members of the Society, and on motion he was authorized to appoint a committee to prepare memoirs. The committees appointed consisted of Messrs. Charles A. Allen and Lucian A. Taylor on memoir of Mr. Ball, and George A. Carpenter and Morris Knowles on memoir of Mr. Heywood.

While waiting for the committee to report a nominating committee, Mr. FitzGerald gave an interesting account of the recent annual meeting of the American Society of Civil Engineers in New York.

The thanks of the Society were voted to James A. Fenno, Supt. of the Boston, Revere Beach & Lynn R. R. for courtesies shown the members of this Society on the occasion of the trip to the tunnel at East Boston.

The literary exercises of the evening consisted of a very interesting paper by Mr. Corydon T. Purdy, C.E., of New York, entitled "The Use of Steel in Large Buildings" The paper was very fully illustrated by lantern views of a number of the most noteworthy high buildings in New York, Chicago and Buffalo.

After passing a vote of thanks to Mr. Purdy for his valuable and interesting paper, the Society adjourned.

S. E. TINKHAM, *Secretary*.

Association of Engineers of Virginia.

ROANOKE, VA., JANUARY 26, 1895.—The annual meeting of the Association was held January 26, 1895, the President, Mr. Charles S. Churchill, in the chair. The directors reported as follows:

Total members on roll, January, 1894	86
Resigned or dropped from roll during the year	50

Members in good standing on roll, January 26, 1895	36
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Active members, 34; honorary members, 2.

Treasurer's report below shows the receipts and disbursements for the year 1894:

RECEIPTS.

Cash balance, January, 1894	\$ 1 92
From initiation	13 75
“ annual dues of 1892	12 50
“ “ “ 1893	30 00

From annual dues of 1894	\$176 25
“ “ “ 1895	140 00
“ sale of furniture	113 50
“ publication	1 00
	<hr/>
	\$488 92

DISBURSEMENTS.

For advertising	\$ 2 10
“ rent	177 32
“ incidentals	46 10
“ good roads convention	10 00
“ publications	94 88
Cash balance	158 52
	<hr/>
	\$488 92

The year 1894 has been a memorable one in the history of our Association, having been witness to the scattering of our members to all parts of the country to meet the requirements of their profession.

The above statements of membership and finances show that the expectations entertained at the beginning of the year were not fully realized. At the last annual meeting there was to the credit of the Association in uncollected dues from members supposed to be in good standing, \$552.50. It was expected that an improvement in business would make possible the collection of a large portion of this amount and so enable the directors to make a publication of the papers on hand. After much labor on the part of our Treasurer, our collection on back dues amounted to only \$218.75, or a total of less than our expenses plus our indebtedness on the last issue of our proceedings. At the fall meeting, on recommendation of the Directors, it was decided that the Association of Engineers of Virginia should give up its old room in the Terry Building, Roanoke; sell its useless furniture (retaining desk, press, etc.); pay off its indebtedness with the amount realized by the sale; accept the kind offer of the Norfolk and Western Railroad Company, allowing us the use of a room in its office building, at Roanoke, for records and meetings; and, finally, join the “Association of Engineering Societies,” so as to secure to our members monthly publications during the year 1895.

All these plans have been completed. Thirty members have paid their dues in advance for the year 1895, and we count our active membership as thirty-four. The Association is out of debt. There is \$158.52 in the treasury to meet all expenses during the year 1895, and our Treasurer estimates that our expenses for that year will be only \$145. Finally, our society has formally become a member of the “Association of Engineering Societies,” along with the societies of Boston, Cleveland, Chicago, St. Paul, Minneapolis, St. Louis, Kansas City, Denver and Montana; and a monthly publication of considerable value will reach our members, beginning with the January number of 1895. These proceedings will be sent direct to our members by the “Association of Engineering Societies,” the first number being due about March, 1895.

During the year 1894, three regular meetings and six monthly informal meetings were held, during which twelve topics were discussed and six papers were read and referred to the Committee on Publication. The summer meeting at Alleghany Springs was regarded by all a success.

The building laws compiled by the Association were adopted by the City of

Roanoke. Our Association took an active part in the presenting of a form of road law before the State Legislature, and considerable expenditure was made by the Association and by its individual members to secure action at an early date.

This report of the Board of Directors was approved.

The President announced the election of officers for the year 1895 to be in order, and appointed as scrutineers of the ballots, Messrs. Crueger and Dunlap, who reported as follows: For President, J. C. Rawn; Vice-president, M. E. Yeatman (to serve two years); Secretary, John A. Pilcher; Treasurer, James R. Schick; Directors (to serve three years), Charles S. Churchill, L. S. Randolph, and H. C. Macklin. Mr. Charles S. Churchill was elected as the representative of the Association of Engineers of Virginia on the Board of Management of the "Association of Engineering Societies."

The Articles of Association of the "Association of Engineering Societies" were adopted, and the Secretary authorized to notify that Association accordingly. The Secretary was authorized to have printed a list showing addresses of all members, for the use of the "Association of Engineering Societies."

A paper by Mr. J. E. M. Hanckel, entitled "Road Improvements in Knox County, Tennessee, and Fulton County, Georgia," was read, and, after discussion, referred to the Publication Committee. This paper re-enforced the arguments brought out before in this Association for the adoption by the State of Virginia of the Road Law as proposed by the Association of Engineers of Virginia, and showed that convict labor can be most successfully employed on this class of public improvements.

J. A. PILCHER, *Secretary*.

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XIV.

FEBRUARY, 1895.

No. 2.

PROCEEDINGS.

Western Society of Engineers.

THE ANNUAL MEETING (323d of the Society) was held in Parlor 44, Grand Pacific Hotel, Chicago, at 8 P.M., on Wednesday, January 2, 1895.* 111 members and guests present.

President H. B. Herr took the chair and called the meeting to order. No objections being made, the minutes of the previous meeting were approved as printed.

The report of the Board of Directors was read by the Secretary, as follows:

At the meeting of the Board held December 12th, the applications for membership of Messrs. George B. Christie, Ferd G. Gasche, George A. Lederle and Jesse Lowe were received and placed on file.

The Committee on Nominations submitted the following list of nominations for the offices to be filled at the annual election:

President,	Willard A. Smith.
First Vice-President,	Onward Bates.
Second Vice-President,	T. T. Johnston.
Secretary,	Thomas Appleton.
Treasurer,	David L. Barnes.
Librarian,	Charles J. Roney.
Trustee,	Hiero B. Herr.

The list was signed by the entire Committee and by eight other members of the Society.

Messrs. Bates, Appleton and Herr declined the nominations.

At the meeting of the Board held December 19th, a petition signed by ten members of the Society was received, nominating Mr. Horace E. Horton for Presi-

* Manuscript received February 25, 1895.—*Secretary, Assn. Eng. Soes.*

dent, and Mr. Charles L. Strobel for First Vice-President. Another petition was received signed by ten members nominating Mr. Charles J. Roney for Secretary.

Mr. Strobel declined the nomination for First Vice-President.

In accordance with the provisions of Section 3 of Article IX of the By-laws, the Board made the following nominations, so as to present a ticket with two names for each of the offices:

For First Vice-President, Daniel W. Mead, L. P. Morehouse.

For Second Vice-President, Henry C. Draper.

For Secretary and Librarian, Edwin G. Nourse.

For Treasurer, W. L. Stebbings.

For Trustee, John W. Cloud, G. A. M. Liljencrantz.

The time for closing the polls was fixed at 12 noon, January 2, 1895. Messrs. J. J. Reynolds, Ralph Modjeski and R. H. Bethel were appointed tellers to receive and count the votes at the annual election.

The resignations of Messrs. Geo. D. Stonestreet, Wm. Forsyth and Charles W. Stewart were accepted.

Bills amounting to \$140.13 were approved and ordered paid.

At the meeting of the Board held this day, the following named gentlemen were elected to membership:

As members, W. I. Babcock, George B. Christie, Howard A. Coombs, Ferd G. Gasche, Chas. W. Hotchkiss, George A. Lederle, Jesse Lowe, John C. Nickson, H. F. J. Porter, Edwin C. Reynolds, William H. Stearns and Charles H. Wilson.

As Associates, Charles E. Schauffler and C. H. Vehmeyer.

The resignations of F. L. Clerc, W. C. D. Gillespie, George D. Hersey and Charles W. Maynard were accepted.

Bills amounting to \$316.32 were approved and ordered paid.

The following report of the Committee on Life Members was accepted and referred to the Society:

To the Board of Directors of the Western Society of Engineers:

The Committee to whom the standing of the Life Members of the Society was referred, submit the following report:

The Western Society of Engineers came into existence at the time of its incorporation in 1880. It was a new organization at that time, its only connection with the old Engineers' Club of the Northwest being that the members of that club became the charter members of the Society.

The provision of Section 6 of Article IV of the Constitution provides that a member who has been a member for 20 years may become a Life Member in the manner provided in the By-Laws.

Section 7 of Article IV of the By-Laws provides that any member who shall have paid all fees, dues or assessments that may have accrued against him for a period of 20 consecutive years, shall, *upon vote of the Board of Directors at any regular meeting*, become a life member.

Your Committee does not see how the provision of the Constitution can be held to cover a period antedating the organization of the Society. Your Committee is unable to learn that any such votes have ever been passed by the Board of Directors. In a strictly legal view, the Society has no Life Members, except Mr. Morehouse, who was specially made so by vote of the Society.

Your Committee, however, believes that it would be unwise to enforce this legal condition in relation to those who have been treated as Life Members in the

past, and recommends that they be excused from payment of all past and present dues; but that in future no other member shall be considered a Life Member until made so by vote of the Board of Directors, which vote cannot be passed until 20 years after the incorporation of the Society, except in case where a member makes a single payment of \$100, as provided by the Constitution.

GEO. S. MORISON, }
R. W. HUNT, } *Committee.*

The Committee on Quarters reported that it had received an advantageous proposition from the agents of the Monadnock Block, and considered it advisable to accept the proposition and remove the Society's property to that location.

The report of the Committee was accepted, and the Board recommends that the Society appoint the same Committee with power to act.

PRESIDENT HERR:—There being no objection, the report of the Board of Directors will be received and placed on file.

Reports of Committees being in order, the Secretary read the report of the Committee on Memoir of the late Orlando H. Cheney.

IN MEMORIAM.
ORLANDO H. CHENEY,
Died April 13, 1894.

The subject of this memoir was born in Ashtabula, Ohio, November 1, 1839.

He received his primary education in the public schools of that city, and afterwards studied civil engineering in the Grand River Institute. Subsequently he was engaged for two years as a member of a corps of engineers on railroad construction in the State of Ohio.

At the breaking out of the War of the Rebellion, Mr. Cheney enlisted as a volunteer in the 11th New York Battery, and served with distinction through the whole period of active hostilities. His battery formed part of the army of the Potomac, and took part in all the battles in which that army was engaged, Mr. Cheney participating in all of these engagements, except during the time he was confined in the hospital, having been severely wounded in the battle of Gettysburg, July 3, 1863.

After the close of the war, Mr. Cheney located in Chicago, and resided there continuously up to the time of his death. For eight years he was connected with the firm of Wolcott & Fox, City and County Surveyors, Mr. Wolcott at that time occupying the official position of County Surveyor.

He was appointed assistant engineer in the Street Department of the city in 1874, and in that capacity had charge of the construction of several viaducts, including the Blue Island and Milwaukee Avenues, in addition to a very extensive list of street improvements in the West Division.

From this position he was promoted, in 1881, to the responsible office of Superintendent of Sewers, which he held continuously up to the date of his death.

In this difficult position Mr. Cheney made a record for ability, integrity, tact and close attention to all details of business, which it is safe to say has been equalled by few men holding political offices in this country.

The fact that he remained undisturbed through so many changes of administration is a proof of the esteem in which he was held by his superiors in the city government, while he won the respect and affection of his subordinates and employees, almost without a single exception.

The taxpayers and property owners felt that their interests were safe in his hands, and even the contractors, whom he held to a strict discharge of their obligations, were free to admit that he was a thoroughly fair-minded man, and that no just claims of theirs ever failed to receive due consideration from him.

But perhaps Mr. Cheney's most prominent characteristic as a public official was his practical realization of the fact that such an official is, first and foremost, the servant of the public. No one who came to him for information or advice could complain of a lack of courteous attention; however busy he might be, he would take personal charge of the applicant for information and look up the data required, often at a considerable sacrifice of time; while a poor man was treated as courteously as a millionaire.

The immense extension of the corporate limits of Chicago, which took place during Mr. Cheney's incumbency of the position of Superintendent of Sewers, caused an enormous increase in the work of that department, and required executive ability of a high order, together with unremitting attention to details, on the part of the department chief, in order to get and keep the records and accounts in proper shape. Previous to the annexation of the suburban districts, all main sewers were paid for out of the general tax levy, but thereafter the special assessment plan was adopted, involving a great deal of extra office work and important changes in the system of bookkeeping.

During the last four years of Mr. Cheney's life many more miles of sewers were constructed in the city of Chicago than the total existing mileage inside the corporate limits at the time of his appointment as head of the Sewer Department.

In 1871 Mr. Cheney married Miss Laura McMahon, who lives to mourn his loss. Four children (one son and three daughters, all of whom are living) were the result of this union.

Mr. Cheney was elected a member of the Western Society of Civil Engineers April 6, 1886.

He was a member of long standing in the Masonic fraternity, and had attained high honors in that organization, being Past Master of Cleveland Lodge No. 211, A. F. & A. M., Past High Priest of Washington Chapter No. 43, and Past Eminent Commander of Chicago Commandery No. 19, Knights Templar. He was also a member of U. S. Grant Post No. 28, G. A. R.

Mr. Cheney was particularly happy in his home life. His genial character, so admired by his friends, doubly endeared him to his family.

To them, in their bereavement, the sincere sympathy of this Society is tendered.

SAM'L G. ARTINGSTALL,
ROBERT P. BROWN,
F. H. DAVIES.

On motion, it was voted that the report be accepted and placed on file, and that a copy be sent to the family of the deceased.

PRESIDENT HERE :—Under the head of new business I would refer to a portion of the report of the Board of Directors which relates to quarters for the Society. Our present lease expires on the 30th of April next. The Board appointed a Committee on Quarters, and this committee has done some very good work. It has a proposition from the agents of the Monadnock Block for about 1,050 square feet of space for nearly the same rental as we are now paying in the Lakeside Building for about 720 square feet.

It was moved by Mr. Randolph that the same Committee (Messrs. Strobel,

Appleton and Roney) be appointed a Committee of the Society with power to act in securing quarters for the Society. Motion seconded and carried.

PRESIDENT HERR:—The tellers now have ready their report of the election, which I will read :

CHICAGO, JANUARY 2, 1895.

To the Western Society of Engineers :

We, the undersigned Election Judges, appointed by the Board of Directors, having canvassed the votes cast for the election of officers for 1895, respectfully submit the following result.

Total number of votes cast, 170, of which

For President.

Mr. Horace E. Horton	122
Mr. Willard A. Smith	47

First Vice-President.

Mr. L. P. Morehouse	92
Mr. Daniel W. Mead	76

Second Vice-President.

Mr. T. T. Johnston	92
Mr. Henry C. Draper	77

Secretary and Librarian.

Mr. Charles J. Roney	138
Mr. Edwin G. Nourse	31

Treasurer.

Mr. David L. Barnes	105
Mr. W. L. Stebbings	63

Trustee.

Mr. G. A. M. Liljencrantz	98
Mr. John W. Cloud	72

JAMES J. REYNOLDS,
RALPH MODJESKI,
R. H. BETHEL.

I therefore announce the following officers elected for the present year :

President, Horace E. Horton.
First Vice-President, L. P. Morehouse.
Second Vice-President, T. T. Johnston.
Secretary and Librarian, Charles J. Roney.
Treasurer, David L. Barnes.
Trustee, G. A. M. Liljencrantz.

THE SECRETARY:—Mr. President, there is one thing that I hope will not be overlooked. During the whole of this year we have held our meetings in the Grand Pacific Hotel, without any expense to the Society. Last year we paid from \$10 to \$15 per night for the use of a meeting-room. The management of this hotel certainly deserves the thanks of the Society for their generous provision for our welfare in this respect.

Mr. R. P. Brown moved that the thanks of the Western Society of Engineers be extended to Messrs. Drake, Parker & Co., of the Grand Pacific Hotel, for the free use of a meeting-room for the Society during the past year, stating that the Society fully appreciates their kindness. Motion seconded and carried.

PRESIDENT HERR:—Before adjourning to the banquet which now awaits us, I wish to thank the members for their assistance during the past year, and for not making the President any more trouble than seemed necessary. I hope that the next year may be more prosperous than this has been, and that you may sustain your new President as fully as you have the retiring one.

The meeting then adjourned to the banquet hall adjacent, where, after a time had been spent in appeasing the hunger and thirst of the members and guests, the meeting was again called to order by President-elect Horton, Chairman of the Committee on Excursions and Entertainments, and a song, "The Chorister," by Masters Davison and Soden of Grace Church Choir, accompanied by Professor Henry B. Roney, was listened to.

The report of the President for the year 1894 was then read by the retiring President, Mr. H. B. Herr, as follows:

The Western Society of Engineers:

GENTLEMEN:—Our By-Laws provide that "at the Annual Meeting the President shall present a report containing a statement of the general condition of the Society and a summary of engineering progress during the preceding year." This latter provision was probably framed when we were styled the "Civil Engineers' Club of the Northwest," and the term "engineering," was meant to be used in a limited sense, to include only what might be classed as civil engineering. A summary of such progress might be essayed, but to summarize the progress of all branches of engineering, and present it at one reading, seemed impracticable. So I trust you will pardon my limiting the report to the "condition of the Society."

Those members who availed themselves of the opportunity for attending our meetings, visiting our library room, and enjoying the delightful excursions made, have much of the information this report contains, but those who could not, or did not, come into such close contact with the operations of the Society, may find something of interest in what will be briefly stated.

As per our Secretary's report, we commenced the year just closed, with 338 members of all grades, of whom 5 have since entered into their last sleep. Resignations have added 14 more to our losses. Yet at the close of the year our membership numbers 416, including all grades. There are several cogent reasons for this handsome rally to our ranks. The able and affable manner in which our Secretary conducted his office; the growth in usefulness of our library; the pleasant and profitable excursions made; the laudable efforts of several members; the appointment of a Reorganization Committee; and the general policy of our Board of Directors. These were undoubtedly the main inducements offered which attracted our new membership.

By pursuing the same economical financial policy as that inaugurated by the preceding Board, our Directors paid out of last year's income, for expenditures incurred during 1893, \$781.72; also all the expenses for 1894, and have saved out of that income a small amount (\$96.42) which they present, as a New Year's gift, to the incoming Board. In addition, they hand over all collections, to date, of dues for 1895. (See Secretary's report). It is worthy of remark that this is the first time for some years that the income for any one year was not raided for payment of expenses of the preceding year. May we not then rejoice in the realization of a healthy financial basis? Yet it is far from a solid one. This will only be when all our ordinary expenses, at least, are paid out of the income for the year

in which they are incurred, without a subscription list, and after placing all initiation fees in a permanent fund.

In taking up their labors, the Board of Directors, in comparing the probable expenses, including those for 1893 unpaid, with the probable income for the year, found that the necessary expenditures for assessments to be levied by the Association of Engineering Societies, rent, janitor services, printing proceedings, stationery, postage, etc., would probably absorb more than the income. On account of the unexpectedly large addition to our membership, this hypothesis was incorrect, as shown by the small balance the other way.

Under such conditions, they found it inexpedient to recommend the payment of salary to the Secretary and Librarian from the Society funds, but favored a subscription for that purpose. The amount of this subscription, as determined by the Society, was to be \$1000.00. Surely a paltry sum for the valuable services rendered, yet it was not all collected, though a special committee for the purpose made an earnest effort towards its consummation. The deficiency of \$102.60 was paid by the Board from the Society funds, with the idea that any further collections should go to that fund.

The necessity for resorting to subscription for the payment of indispensable services was one of several important considerations which led to the recommendation, by the Board, of our withdrawal from the Association of Engineering Societies.

A library room, with a competent librarian in attendance daily during ordinary business hours, was a new feature inaugurated last year. Such attendance could not have been had but for the generous offer of Mr. Roney to give the attendance for such remuneration as the Society might award him, and for benefits to result towards building up a creditable library.

At the beginning of the year we had about 1,070 bound volumes, about 4,200 unbound volumes, magazines and pamphlets, with about 900 maps, charts, atlases, etc. These were uncatalogued, and of little use to the Society. Now we have about 2,000 bound volumes, and about 7,800 unbound volumes, periodicals and pamphlets with a large increase of maps and charts. About 2,000 of these are classified and listed for ready reference, and a librarian is in attendance. From my own observations I am sure many members can testify to profitable time spent in gleaning therefrom during the past year.

The great accessions to the library must be attributed to the earnest efforts of our librarian in soliciting, and the liberal spirit of a number of our members in making donations, aided by such assistance as the Committee on Library afforded. The meagre salary, \$500.00, paid the librarian, Mr. Roney, for his valuable services during the year, was, as you all know, entirely incommensurable with the value received, and the thanks of the Society are due him for his unselfish zeal in devoting so much of his time to our benefit. From what has been done in the past year, may we not hope to secure in the near future, to the profession and to this city, a library creditable to the times, the place, and our Society?

When we consider the secretarial labors incident to the holding of 13 meetings of the Society; 27 meetings of the Board of Directors, with a great deal of committee work, looking up papers to be read before the Society (13 in number last year), and the many other calls upon the Secretary's time, we must admit that such services are worth much more than the paltry \$500.00 he received for the entire year's work, if efficient service is given. That our Secretary, Mr. Appleton, has conducted the affairs of the Society in a highly satisfactory manner, is evident to

every member of our Board of Directors, at least. The records are in admirable condition, and we have prospered well under his careful methods and general comradeship; he is eminently entitled to the thanks of the Society.

Excursions to various places of interest and instruction were a marked feature of last year's conduct of the Society. Our Committee on Excursions and Entertainment deserves our thanks for the valuable time devoted to our pleasure and our general welfare in planning and carrying to completion so many pleasurable excursions, and without using a dollar of the Society funds.

At our February meeting, a Committee on Reorganization was created for the purpose of preparing a new Constitution and By-Laws, adapted to the needs of an Engineering institution on a higher and more national plane than our present organization. This Committee commenced its labors with much enthusiasm and gave promise of a great stride towards that eminence which we should reach at an early day. But alas! the summer heat came, and, like the prairie's verdure, it withered, but not to revive again with the cooling rains of autumn, as did the grass on plain and slope; so we are still under the old Constitution and By-Laws. And this in Chicago!—where are monuments on every hand proclaiming such rapid advances in business, in art, in architecture and engineering as are not, and have not been, elsewhere on this planet.

Engineers have been styled—and properly too—the pioneers of civilization. Why then does our Society follow in the wake of this stupendous march onward? Why not leap to the front, keeping pace with our City's progress, and take a leading place amongst the Engineering Societies of this country? Why not take up the Chicago spirit which secured the site for, then conceived and carried to completion, the grandest World's Fair mortals have ever beheld? That spirit, which is cutting through soil, drift and rock, our ample drainage channel, magnificent in its proportions, invaluable in the benefits it will secure to our City, and eventually to the commerce of the entire country? That spirit, determination and enterprise, in short, which has made Chicago the wonder of the world? In my opinion, Gentlemen, you will be "behind the times," in comparative obscurity, until you take on a National character, and stand upon the high plane compatible with nationality.

Had our business men been terrified by the New York idea, that Chicago was not competent to present a successful exhibition to the world, and yielded to the demands of that city, the site for the World's Exposition, is there one of you to-day who will say that a city of such magnificence would have been erected there as was the fair "White City" reared upon one of our primeval swamps? Why then heed the mutterings, from that same quarter, against our advancement to the highest place, and against the publication of our own productions, as is done by almost every other kindred organization the world over? See editorial in *Engineering News*, November 15, 1894. You should all read that. It is well calculated to increase the ranks of our "turbulent members." The last two words are quoted from the editorial.

Although we may congratulate ourselves for the progress made in certain directions during the year, I must confess that all was not accomplished which should have been, and might have been effected under a stronger guiding hand. Let me assure you, however, that any remissness on my part was due to my incapacity for the honorable position you thrust upon me, and not to willful negligence or lack of interest in the Society's welfare.

I wish to make note of my high appreciation of the consideration and courtesy accorded me by the officers and members generally. Thereby you and they

greatly facilitated my labors as presiding officer, and made for me a pleasurable duty, what had otherwise been a disagreeable task.

My greatest pleasure in the way of my official functions comes at this moment, in proposing the health of my wisely selected successor. He is known to you as one of our most useful members, one of our best engineers, and I know he will be one of our very best presidents.

Long life and prosperity to our genial fellow-member, and a happy reign to our President, Mr. Horton.

MR. HORTON:—The members of the Society know that the Board of Directors is required to see that at least two names are on the ticket for each office to be filled at the annual election. On one occasion the Board had to make the entire list. I have been honored with a place on the ticket so frequently, and have so often been "turned down" without an opportunity to make a speech, that I am now placed in an unexpected position, and have nothing to say in the way of an address, and in that connection I will call on Mr. Willard A. Smith, who will, I trust, say those things that I would like to say.

MR. WILLARD A. SMITH.—Mr. President and Gentlemen, this is hardly fair. Mr. Horton and I made a blind deal on this matter and had an excellent address prepared between us, and as he was the successful candidate he should have delivered it, and now, with that address in his inside pocket, he calls on me for a speech. . . . I can only take this occasion to congratulate the Society on the very decided progress which it has made during the year, and which it has so admirably crowned in its selection of officers for the coming year. I predict for the Society a year of greater prosperity than it has ever yet had. I fully agree with the remarks of our retiring President regarding the future of the Society and what it should be. I fully agree with him that no men and no society ever achieved greatness without first having planned for greatness and attempted it, and that this Society will never meet the full demands of its location, will never rise to the opportunity which is its opportunity, until it does plan for great things. Those who always fear that they may be going ahead too fast, never will get there. That is especially true of societies of this kind. It is especially true of Chicago. . . .

If we have the ambition, if we have the nerve to attempt it, we may achieve very great things. Chicago looks to us to do it, the country looks to us to do it, the world looks to us to do it. I believe fully that we should reorganize and make every attempt in our power to place ourselves in that position which our retiring President has so well placed before us to-night.

Mr. Horton then called on Mr. N. B. Patton, President of the Municipal Improvement League, who spoke of the work of the League in attempting to guide public sentiment and official bodies so as to avoid the construction of monstrosities.

At the suggestion of Mr. Horton, Mr. Appleton then read the following communication from Mr. E. L. Corthell :

"Mr. E. L. Corthell sends to Mr. Appleton the compliments of the season and best wishes for the new year for himself and the society he has so ably served the past year. May there grow out of this year's hard work and out of the abundance of good elements and talents, a greater society on a broader basis and a deeper foundation. Health is returning.

"BERNE, Suisse, December, 1894."

MR. RANDOLPH :—May I suggest, Mr. President, that this Society transmit to our ex-President its new-year's greetings, and the hope that he may be speedily restored to health.

MR. HORTON :—The sentiments shall be sent as the sentiments of the Society. (A telegram was sent by cable to Mr. Corthell at this time.)

Song "Old Folks at Home," by Master Charlie Davison. Mr. George H. Wilson, President of the Engineers' Club of St. Paul, then responded to a call from Mr. Horton with some felicitous remarks.

MR. HORTON :—Gentlemen, we are all engineers here this evening, but when I call, as I do, for the greatest of our engineers, I am belittling none of the others. We will now listen to Mr. George S. Morison.

MR. MORISON :—Mr. President, I wish you had not called me up in that way, which makes me feel so much responsibility. I was very much gratified with the definition which our recent President gave of engineering, and I trust that I may apply that to the present occasion and say that as he defined engineering to be a thorough knowledge of the Western Society of Engineers, that there is no one here who wishes better for the future, the present and all the good of the Society than I do.

A great deal has been said about the Western Society, and there are a few things which I would like to call attention to. It is said that we have turbulent members. Turbulent members may be divided into two kinds. It is said that there are kickers in this world, and that there are croakers. The kicker makes a fuss and accomplishes his object, the croaker does nothing but find fault. I think that we may say that the turbulent members are all kickers. I do not think that we have many croakers. And I believe that their kicking has done a great deal of good. I believe that we did a great deal of good when we kicked at the Association of Engineering Societies, and I am very glad that the Association kicked back. We had a kicking match, and we are still in. I do not think it has done anybody any harm, and I think it has done all a great deal of good.

Now we have had a Committee, which, I understand from what has been said before, is no longer on the subject of reorganization. We are engineers, and as engineers we are supposed to understand mathematics, and to know that there is more than one dimension in this world. An account has been given of a strange race who lived in the land of one dimension and could only move in one direction. Now I think the Western Society made its great advance when it took its present name and its present character. That was nearly fifteen years ago. What was once the Civil Engineers' Club of the Northwest became the Western Society of Engineers; it discarded the word "civil," it merely said it was a Western Society, but not merely a Western Society of Civil Engineers. We have a national Society of Civil Engineers, another of Mechanical Engineers, another of Mining Engineers, and various others. All those Societies have extension in two dimensions, but they are both horizontal dimensions; they have an indefinite geographical extension, but a limited professional extension. I do not see why the Western Society cannot make its extension in the remaining dimension instead of trying to be a National Society. It cannot be the only society of the country, but it can be the leading society which embraces all kinds of engineering. That is its true method of extension, and that is the true meaning of the step it took when it reorganized

fifteen years ago, when it adopted its present name and when it began to become what it will very soon be.

Our past President has given us a pretty full statement of what this Society has done during the past year. It is a plain statement of dollars and cents. The Society, which was heavily in debt a year ago, has now a small surplus on hand. If, during the coming year, it does no better than it did last year, it will be able to pay all its current expenses, including its salaries, out of the receipts of the coming year. If it does that next year, as I fully expect it will, one year more will put it on the basis of paying its expenses out of what are strictly revenues, without in any way encroaching on admission fees or other things which by any possibility can be called capital.

It seems to me that we are doing well, and that we have simply to keep on as our past President and Secretary have helped us to do in the past, and as I believe our new President and Secretary will do in the future, to make the Society all that any of us really want it to be, the leading society of the West in every branch of engineering.

Judge Vincent, of the Civic Federation, was then called on by Mr. Horton, and, in the course of his remarks, said: "I know of no class in the community who are more thoughtful, who are more intelligent, than those who devote themselves to the profession of engineering, and it has been a matter of surprise and a matter of regret to me in the experiences which I have already related, that men who have such tremendous responsibility, who have interests of such magnitude intrusted to them, both as to their ability, their capacity and their honesty, are so poorly paid. I know of no professional men in the world who render so great and so valuable services at such small remuneration as does an engineer, and I hope the time will come when the laborer who is an engineer will be worthy of his hire, and that his brothers in the profession will not attempt to cut down his fees, but will do as they do in the law, sustain him in any fair, reasonable and liberal charge."

(Song, "The Fisherman," by Masters Davison and Soden.)

Mr. Horton then called upon Mr. Randolph, who spoke of the work under his charge, the Sanitary District Canal.

Mr. Horton then called on Mr. B. L. Crosby, of the Engineers' Club of St. Louis, who, in responding, said: I was very much interested in hearing how you manage your affairs over here, particularly as regards your library. Our St. Louis Club is much smaller than yours, and on account of our small membership we cannot pay salaries so as to have our library properly taken care of, hence it is of little use to us. During the hard times of the past year we have just about held our own as to membership, and we close the year with a small cash surplus and no debt.

Now that I have seen what your membership is, I think that if I had been a member of the Western Society I should have joined most heartily in your movements to withdraw from the Association of Engineering Societies. I think such a Society as yours is well able to take care of itself. (Applause.)

As smaller societies, we could not afford to publish our papers, and I think the Association, which was formed for that purpose, is a grand thing; but whenever the St. Louis Club gets so it can stand on its own feet, as you evidently can here, if I am still a member of the Club, I shall advocate some such move as you attempted.

But I can say, on the part of the St. Louis Club, that we are very glad that you did not withdraw, and that you are still with us to help carry the load. . . .

We should be very glad to welcome any of you gentlemen at our meetings at any time you may be in St. Louis. I think we have a good club and I extend to you all a hearty welcome. (Applause.)

Remarks were also made by Professor Hatch, of the Armour Institute; Mr. Lorado Taft, of the Chicago Society of Artists; Mr. McCarthy, of the Builders' and Traders' Exchange, Mr. Lyman E. Cooley, and Capt. Robert W. Hunt, after which, owing to the lateness of the hour, the meeting adjourned.

THOS. APPLETON, *Secretary*.

APPENDICES.

- I. Report of Secretary for the year 1894.
- II. Report of Auditors (Financial Statement, 1894).
- III. Report of Board of Managers Association of Engineering Societies.

APPENDIX I.

ANNUAL REPORT OF THE SECRETARY FOR THE YEAR 1894.

To the Western Society of Engineers:

At the beginning of my term of office the records showed the total membership of the Society to be 338

Since that time the losses have been:

By death,	5
" resignation,	14

Total losses, 19

During the year there have been elected:

Members,	63
Associates,	25
Juniors,	2
Delinquents reinstated,	7

Total additions, 97

A net gain of 78

Making the total membership at present, including those recently elected, but not yet qualified, 416

Comprised of Members,	389
" " Associates,	25
" " Juniors,	2

Death has been an active agent in cutting down our membership list this year. The following have passed over to the great Majority:

Wm. H. Lotz,	who died	January 31st.
Abraham Gottlieb,	" "	February 9th.
Isaac Lincoln,	" "	March 13th.
Orlando H. Cheney,	" "	April 13th.
Joseph P. Card,	" "	October 22d.

During the existence of this Society many have lost their rights to membership through failure to pay dues. So far as the present Secretary has been able to ascertain, there is no record of any such person having been officially dropped from the rolls of the Society previous to January 3, 1894. At that time 96 names were dropped from the rolls of the Society for delinquency. In some cases this delinquency extended back several years; in others it was for the year 1894. Seven members, who were cut off a year ago, have paid up all arrearages and have been reinstated. The sum of the amounts due from delinquents of one year ago was \$1,546.00. Of this amount, \$92.50 has been collected this year.

The number of cases of delinquency for 1894, which will be reported to the next meeting of the Board of Directors is 14, with a total amount of \$130.00.

The Society has held 13 meetings during the year, departing from the usual custom of omitting the July and August meetings. The attendance at meetings has varied from 30 to 91, averaging 55 per meeting.

The following papers have been read:

February 7th, "A Method of using High Explosives as a Means of Propulsion in Aërial Navigation," by Dr. Pynchon.

March 7th, "Original Construction of the Burlington Bridge," by Mr. C. H. Hudson, M. W. S. E.

April 4th, "Some Notes on the German Collective Exhibit of Engineering at the World's Columbian Exposition," by Mr. Charles J. Roney, M. W. S. E.

May 2d, "The New Tunnel of the West Chicago Street Railway under Chicago River near Van Buren Street," by Mr. Charles V. Weston, M. W. S. E.

June 6th, "Typhoid Fever and the Epidemic at Ironwood, Michigan," by Mr. E. A. Rudiger, M. W. S. E.

June 6th, "The Halsted Street Lift Bridge," by Mr. Samuel M. Rowe, M. W. S. E.

July 11th, "The Covered Reservoir of the Rockford Water Works," by Mr. Charles C. Stowell, M. W. S. E.

Same date, "The Corrosion of Iron Pipes by the Action of Electric Railway Currents," by Mr. D. C. Jackson, M. W. S. E.

August 1st, "A Prefatory Description of the Organization and Works of the Sanitary District of Chicago," by Mr. Isham Randolph, M. W. S. E.

September 19, "Strains and Deflections in Solid Bridge Floors," by Mr. Henry Goldmark, M. W. S. E.

October 3d, "Notes on a Broken Pinion Shaft," by Mr. Onward Bates, M. W. S. E.

October 3d, "General Hydraulics of the Chicago Main Drainage Channel," by Mr. T. T. Johnston, M. W. S. E.

November 7th, "Refrigeration by Carbon Dioxide," by Mr. E. F. Osborne, M. W. S. E.

December 5th, discussion of Mr. Goldmark's paper.

A total of thirteen papers, five of which have been printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

All the meetings of the Society during the past year have been held in the Grand Pacific Hotel. Thanks to the generosity of Messrs. Drake, Parker & Co., proprietors, we have been provided with excellent accommodations without any expense whatever to the Society. This fact is apparent in the balance sheet for the year. In previous years the Society has paid from \$10 to \$15 per night for a meeting room.

The Secretary felt, on entering upon his duties, that in the past the social

phase had not been sufficiently developed, and so set to work, with the approval of the Board of Directors, to encourage this feature. It seemed desirable to provide opportunities for conversation, to afford some means for the members to become better acquainted with one another. With this end in view he arranged to keep the rooms of the Society open during a greater part of the business hours every week day, so that members might have an opportunity of meeting there. He also made the customary announcement, on notices of meetings, that those who could do so conveniently would sit down and eat together on the evening of the meeting, in the Grand Pacific Café. Many of those who have attended these informal lunches, which enabled them to while away the gap between office closing time and meeting time, have declared them to be an important and interesting adjunct of the formal meetings.

To still further develop the social features, excursions were arranged; the first to the Van Buren Street Tunnel and Power House of the West Chicago Street Railway, April 14th. This was attended by 75 members and guests.

The second excursion was a trip on the South Branch of the Chicago River, June 2d, to see the bridges at Canal and Halsted Streets, and the pumping works at Bridgeport. Transportation on this occasion was provided by Messrs. Shailer & Schniglaui, members of the Western Society of Engineers, who kindly placed their steam barge "Burrows" at the disposal of the Society. Eighty members and guests enjoyed this trip.

Soon after this, a Committee on Excursions and Entertainments was appointed, whose active efforts have provided the Society with a series of pleasant excursions.

August 16th, an excursion on the lake was made by Steamer "Ivanhoe" to South Chicago and thence to Fort Sheridan. Ladies, guests and members, to the number of 140, enjoyed a most delightful trip.

September 8th, the first trip to the Main Channel of the Sanitary District of Chicago was made by a special train kindly furnished by the A. T. & S. F. Ry. Some 220 members and guests participated in this interesting excursion. The "all earth" sections at the Chicago end of the line, and the "all rock" sections near the other end, were visited. The party was most hospitably entertained at lunch by Messrs. Gahan & Bryne, Associate Members of the Western Society of Engineers, Contractors for Sections F. and G. of the Channel.

On the 6th of October, the second trip to the Sanitary District Channel was made. The Chicago & Alton R. R. kindly furnished a special train for the day. Some 258 members and guests enjoyed this trip. The sections located between those visited on the first trip to the Drainage Channel were inspected. Messrs. Griffith & McDermott, Associate Members of the Western Society of Engineers, Contractors for Section I of the Channel, provided an elaborate lunch for the party at their camp.

November 17th, a trip to South Chicago, taking in several of the important manufacturing industries of that thriving locality, was made by a party of 120 members and guests. The Baltimore & Ohio R. R. generously provided a special train for the convenience of the party.

The Society was fortunate in having fine weather on every one of these occasions, which proved most enjoyable and interesting. All of these trips have been made without any draft whatever on the Society's funds; even the printing of circulars and tickets and the postage for mailing the same, have been paid for by the committee. And, finally, the same committee has made all arrangements for the Annual Banquet now about to take place.

A midwinter excursion of the Society to New Orleans has been suggested, but up to the present date no arrangements for it have been perfected.

Early in the year the Secretary found that the work of cleaning, arranging and listing the long neglected library of the Society would occupy more time than he could spare. Hence he resigned the position of Librarian, and the Board of Directors appointed Mr. Charles J. Roney to the vacancy. To the energetic, painstaking and persistent efforts of Mr. Roney the Society is indebted for making our Library of use to the members. Probably very few of our members were aware of the extent and value of our collection of books, charts, etc., or realized how its contents could be built up at comparatively small cost. Of late the Library has been visited by many of the members in search of technical information, who have succeeded in finding on our shelves the desired data.

At the beginning of this year the Society was in debt. Although \$308.28 of cash on hand was reported, \$346.72 of the dues for 1894 had been expended for the payment of 1893 expenses by the former administration, and the \$400 advanced by the Board of Directors was unpaid. During 1894 this loan has been paid, and \$34 of 1893 bills, together with all the bills of 1894, leaving a small balance in the treasury, without touching any of the 1895 dues already collected. In brief \$780.72 of old debts have been paid out of the receipts of 1894, and the Society does not owe a cent. This condition has been achieved through the generous responses of members to appeals for subscription funds for the Library and for the payment of services of Secretary and Librarian. For the Library Fund \$312.68 has been collected, including revenue derived from sale of duplicates, \$187.68 of which had been turned into the Treasury of the Society, with an unexpended balance of \$83.18, and \$125 is in the hands of the Library Committee.

For the Special Fund \$897.40 has been collected, all of which has been expended.

The Secretary, in the early part of his term, cherished hopes of securing many more papers to be read before the Society than have appeared during the year. He had promised of a series of papers on Chicago High Building Construction, which are not yet ready. He thought that a paper on the Methods of Paying for Municipal Improvements by Special Assessment, with a thorough discussion of the subject, would be interesting and pertinent, but before he had secured any material this field was pre-empted by the Real Estate Board.

He has secured promises of papers enough to run through the meetings of the ensuing year, but he realizes that promise and performance are not synonymous terms.

The Society is to be congratulated on the increasing membership, the well-maintained attendance at meetings, the growing library, and its improved financial condition. Whatever efforts the Secretary might have made, these results could not have been accomplished without the hearty co-operation of the Board of Directors, the generous assistance of the Librarian, and the active efforts of many of the members. The Society is but a collective noun; it can only become what its members make it.

Respectfully submitted,

THOS. APPLETON, *Secretary.*

APPENDIX II.

REPORT OF AUDITORS.

Financial Statement for 1894.

RECEIPTS.

Collected by former Secretary	\$655 00	
Expended by former Board in 1893	346 72	
	<hr/>	\$308 28
Delinquent dues		92 50
Resident dues for 1894		1,950 00
Non resident dues for 1894		613 15
Entrance fees		405 00
Hospitality Committee		167 28
Sale of chairs		5 40
Sale of Library Duplicates		7 90
Subscription to Library Fund		12 50
Subscription to Special Fund		897 40
	<hr/>	\$4,459 41
Non-resident dues for 1895		\$67 50
Resident dues for 1895		250 00
	<hr/>	317 50
		<hr/>
		\$4,776 91

DISBURSEMENTS.

Rent, Janitor, Light and Insurance	\$576 36
Postage and Postal Cards	213 25
Stationery and Printing	296 61
Stenographer and Typewriting	114 47
Printing Proceedings	287 00
Journal Association Engineering Societies	1,146 10
Library	131 28
Furniture and Shelving	53 14
Deficiency on Banquet, January 3, 1894	67 00
Repayment of Loan advanced by Directors in 1893	400 00
Engrossing	30 00
Express Charges and Incidentals	44 64
Exchange Charges on Checks	3 15
Salaries	999 99
	<hr/>
	\$4,362 99
Cash Balance December 31, 1894	413 92
	<hr/>
	\$4,776 91

THOS. APPLETON, *Secretary.*

The undersigned, forming the Auditing Committee of the Board of Directors, have examined the Secretary's books and compared the same with the Treasurer's books, and find the foregoing account to be correct and the payments supported by vouchers duly authorized by vote of the Directors.

C. L. STROBEL,
GEO. S. MORISON,
ROBERT W. HUNT.

APPENDIX III.

CHICAGO, JANUARY 1, 1895.

To the Western Society of Engineers :

GENTLEMEN :—In accordance with the requirements of the By-Laws, your representatives in the Board of Managers of the Association of Engineering Societies would respectfully report that at the beginning of the year 1894, Mr. J. C. Trautwine, Jr., was elected Secretary of the Board, and the JOURNAL OF THE ASSOCIATION has since been conducted by him. For a portion of the time the publication has been somewhat behind in its issue. With the close of the year, however, the issue is well up to date, the November number having been distributed some time near the 20th of December. This is as nearly on time as it is generally practicable for such a publication to be.

The character of the JOURNAL in its make-up, and the matter published, has in every respect been maintained, and in many ways improved.

Up to, and including the November number, there has been published during the year 676 pages of reading matter and 106 pages of proceedings of Societies, without counting the index notes. It is estimated by the Chairman of the Association that, not counting the index notes, but including the December number, there will be published for the year 820 pages, which is an increase of about thirty per cent. over the greatest amount of matter heretofore published by the Association during one year.

By a statement of expenditures made by the Secretary, which includes an estimate of the cost of the November and December numbers, the assessment of \$3.00 per year will fall short of meeting the expenses of the Association by about \$500, which will probably render a special assessment of 40 cents per member necessary to meet the year's expenditures. This additional expense is mainly due to the increased amount of matter published, and to the expensive nature of some of the illustrations, and to additional expenses incident to the change of the place of publication. It is hoped that another year will bring about results which will keep the expenditures within the usual limits.

The Board of Managers of the Association have under consideration measures which it is hoped will better meet the requirements of the Societies, particularly in the way of advanced papers. Though upon this subject, as upon others, no final decision has been reached, it is confidently expected that the needs of each Society belonging to the Association will be met.

Respectfully submitted,

BENEZETTE WILLIAMS,
THOS. APPLETON.

[The Report of the Managers on the part of the Western Society of Engineers in the Association of Engineering Societies was received too late to be read at the annual meeting, but is submitted herewith. Owing to the absence of Mr. John Nichol from the State it has been impossible to get his signature to the report.—T. A.]

ERRATA.

In the Proceedings for 1894, as printed, the following corrections should be made:

No. 313, page 2, 8th line, for Alexander W. Gates, read Andrew W. Gates.

No. 320, page 2, 4th line from bottom, for E. A. Eckhart, read B. A. Eckhart; page 3, 6th line, for Braasche, read Braasch.

No. 322, page 2, 2d line, for Wm. C. Stearns, read Wm. H. Stearns; 3d line, for O. H. Vehmeyer, read C. H. Vehmeyer; 2d line in foot note, for Gaasche, read Gasche.

THOS. APPLETON, *Secretary.*

Boston Society of Civil Engineers.

FEBRUARY 20, 1895.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.50 o'clock P.M. Vice-President George F. Swain in the chair. Number of members and visitors present, including ladies, 118.

The record of the last meeting was read and approved.

Messrs. Samuel G. Armstrong, Henry W. Hayes, and Edward B. Stearns, were elected members of the Society.

The Chair announced the appointment, by the President, of Messrs. George A. Kimball and Austin B. Fletcher to serve as Tellers of Election at the annual meeting.

Attention was called by the Chair to the death of Franklin Darracott, an honorary member, who joined the Society in 1848; and, on motion, the President was requested to appoint a committee to prepare a memoir.

The Secretary read letters from the Boston Society of Architects and the Boston Architectural Club, expressing the thanks of these organizations for the invitation to attend the January meeting of this Society.

Mr. Cope Whitehouse, of New York, was then introduced and delivered a lecture on "The Proposed Reservoir for the Storage of the Surplus Flood-Waters of the Nile, and the Raiyan Drainage Canal." The lecture was profusely illustrated by lantern slides.

After passing a vote of thanks to Mr. Whitehouse for his interesting lecture, the Society adjourned.

S. E. TINKHAM, *Secretary*.

Civil Engineers' Society of St. Paul.

FEBRUARY 4, 1895.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M., President Stevens in the chair. Eleven members and one visitor in attendance.

The minutes of the previous meeting were read and approved.

The Secretary was authorized to print and distribute a list of members and to secure twenty-five copies of the Mr. Woodman's paper on Transition Curves.

The following report of the Committee on the Minnesota Topographical Survey was read and accepted:

REPORT ON TOPOGRAPHICAL SURVEY OF STATE OF MINNESOTA.

To the Civil Engineers' Society of St. Paul, Minn.:

Your Committee, having had under consideration the subject of the topographical survey of Minnesota, begs leave to report as follows:

The importance of such a survey is perhaps not so well understood and appreciated in our Western States as is the case in our Eastern States and in Europe, where the practical benefits of this form of public enterprise have long been enjoyed. A topographical survey of our State, that was rightly planned and executed, would contribute greatly to its development by suggesting many improvements connected with the subjects of transportation, good roads, water supply, hydraulic works, the draining of wet lands, the irrigation of dry lands, etc., and by furnishing at the same time, from maps, data for safe approximate estimates of the cost of such improvements, as is the fact in England, Germany, France and

Switzerland to-day, and even in Massachusetts and New York to a less reliable extent.

Your Committee would therefore advise that the Society express to the Regents of the State University its sense of the value and importance of the geodetic and topographic work thus far done in our State, and recommend that they continue the topographic work as heretofore, not only for the special economic value of the results, but also for the additional object of securing a continuance of the geodetic survey by the United States Coast and Geodetic Survey, which bureau is authorized to establish geodetic points in those States of the Union "which shall make requisite provision for their own topographic and geodetic surveys."

Your Committee would also advise that the Regents of the University be requested to have the topographic survey of the principal cities of the State and their vicinity, together with the principal rivers of the State, made in such detail as is suitable for a map on the scale of 1 : 20,000, which in our opinion is the smallest scale that will yield a map of adequate utility; also, that they continue the work through the agency of the College of Engineering of the University, and, as soon as circumstances will warrant, apply to the Legislature for special appropriations to increase the force employed and thus expedite the work, in order that its results may sooner be utilized by the general public.

Your committee would further report, that the topographical work recently done in this State by the United States Geological Survey, as placed before the public, is on the scale of one mile to the inch, and this scale appears to be adequate to the special objects of the Geological Survey. Although this survey is ably and economically conducted, and will, for a long time to come, be of sufficient accuracy and detail, and of great value for the greater part of this State, it does not secure the amount of detail in the particular districts before referred to, namely, the principal cities and rivers, to give its maps of those districts the general economic value they would possess if executed on the larger scale that we have proposed.

The accurate determination of geodetic points is the first requisite of a topographical survey. Following this, the filling in of details may be by rapid and approximate methods. As now organized, the United States Coast and Geodetic Survey is prepared to fix the geodetic points and the United States Geological Survey to fill in the details and publish the results. We consider it of prime importance to unite harmoniously these branches of the work, and to that end would urge our Senators and Representatives to forward the consolidation of the harmonious relations of these bureaus. Such a bureau should consist of men scientifically and technically fitted for the work, and appointed only under the strictest civil service rules.

Respectfully submitted,

E. E. WOODMAN,
G. L. WILSON,
H. E. STEVENS,
K. E. HILGARD, *Chairman.*

St. Paul, Minn., February 4, 1895.

Mr. Woodman read from the December number of *Popular Science Monthly* a favorable comment, by Prof. Davis, of Harvard University, on the work of the U. S. Geological Survey.

The Librarian was requested to file for convenient reference the index and other sheets of said survey lately obtained for the Society by President Stevens and Mr. Wilson.

Mr. Armstrong reviewed and illustrated three U. S. Supreme Court decisions in the matter of riparian boundaries.

Mr. Münster gave his theory of the fact that two heavily loaded spans of the University Avenue bridge had remained standing after the post common to the two spans had been destroyed by a derailed cattle train.

C. L. ANNAN, *Secretary*.

Engineers' Club of St. Louis.

411TH MEETING, FEBRUARY 6, 1895.—President Russell called the Club to order at 8.10 P.M., at 1600 Lucas Place, there being twenty-six members and six visitors present. The minutes of the 410th meeting were read and approved. The Executive Committee reported the doings of its 181st and 182d meetings. The committee had had a conference with a special committee from the Electric Club, and the two committees had agreed upon a plan for the future care of the Electric Club Library in the Engineers' Club Rooms, which plan both committees agreed to recommend to their respective clubs for acceptance. The Secretary reported that the Electric Club had ratified the report of its committee and that all that was lacking to complete the matter was the approval of the Engineers' Club.

On motion it was ordered that the plan be ratified and that the President be authorized to enter into an agreement with the proper officers of the Electric Club.

The President announced that he had added to the Eads' Monument Committee, Messrs. Julius Pitzman and T. H. Macklind.

The Secretary then read the following letter:

ST. LOUIS, January 30, 1895.

WM. H. BRYAN, ESQ., *Secretary Engineers' Club of St. Louis*.

DEAR SIR:—I have the honor to acknowledge the receipt of your favor of January 17th, in which you notify me that the Engineers' Club of St. Louis has elected me an honorary member, and request you to express to the members of the Club my high appreciation of the honor thereby conferred.

While I feel that the flattering terms in which the information is conveyed are hardly deserved, I may proudly affirm that during a professional career extending over half a century, I have always tried to do my share towards elevating the profession, and that of the work which I did in that direction in which I feel the greatest pride, has been the share taken by me in founding the Engineers' Club of St. Louis.

Although I cannot be a very active member of the Club, I have always taken a most earnest interest in its welfare, and hope that it will continue to grow in number of members and to enlarge its sphere of usefulness.

Very respectfully,

HENRY FLAD.

On motion it was ordered that the letter be spread in full on the minutes of the Club.

The further discussion of Mr. B. L. Crosby's paper upon the St. Louis Extension of the St. Louis, Keokuk & Northwestern R. R., read December 19th, was taken up. Mr. Crosby exhibited a number of lantern slides, showing foundation work on the piers of the Sioux City, Nebraska City, Rulo and Bellefontaine bridges across the Missouri River, and the Alton and Memphis bridges across the Mississippi. The Morison clay hoist and sand pump were described in detail, as were also the details of the caisson work, and the use and construction of air-locks. Figures were given showing the cost of deep foundations at different places.

The hour being late, it was on motion ordered that the reading of Mr. Curtis' paper on "A System of Water Purification" be deferred until the next meeting, February 20th.

Adjourned.

WILLIAM H. BRYAN, *Secretary*.

412TH MEETING, FEBRUARY 20, 1895.—President Russell called the Club to order at 8.20 P.M., at 1600 Lucas Place, with twenty-one members and eleven visitors present. The minutes of the 411th meeting were read and approved. There being no regular or miscellaneous business, Mr. J. H. Curtis then addressed the Club on "A System of Water Purification," which he had developed, with special reference to the removal of organic matter.

He had been experimenting for over two years and had discovered that where sand filters were not submerged, but where the water was allowed to drip upon the sand bed, just as rain falls upon the earth, particles of air followed the drops of water through the sand, making the most complete aëration possible. The author's experiments, however, had only been conducted on a small scale, and he was unable to give any figures as to the actual amount of purification, or capacity of filter beds, based upon actual service.

Colonel E. D. Meier then read a translation of a paper by Professor August Ritter, of Germany, on "The Mechanics of Soaring Flights." The paper was intended to prove mathematically that where wind currents varied in velocity, it was possible for a bird to soar or rise without doing work itself. The paper claimed that repeated observations of soaring birds showed that there was no motion of the wings, and that very delicate observations of wind velocities indicate wide fluctuations.

In the discussion of the paper, Professor Johnson stated that this matter had already been presented in this country by Professor Langley, and that he, Professor Johnson, had answered it very fully in *Aéronautics*. He denied absolutely the premises on which the paper was based, viz.: that a bird did not move its wings or feathers, and that there were such frequent and regular fluctuations of wind velocities. He also showed that even admitting the premises to be true, and placing actual values in the formulæ, the wind velocity remaining available for supporting the bird was entirely too small for that purpose.

Professor Kinealy stated that some years ago Dr. Todd had read a paper before the Academy of Science in this city, showing that the tail or primary feathers of the buzzard were articulated in a way permitting of a motion similar to sculling, and that there were well-developed muscles connected with these feathers. These were found only in soaring birds, and they give the primary feathers a very rapid motion, which it was thought was capable of sustaining the bird. Mr. Crosby and Mr. Wheeler also took part in the discussion, the general trend of which was to the effect that the soaring was accomplished by some motion of the bird's feathers, invisible to the naked eye.

Adjourned.

WILLIAM H. BRYAN, *Secretary*.

Montana Society of Civil Engineers.

FEBRUARY 9, 1895.—The regular meeting of the Montana Society of Civil Engineers was held at the Society rooms, in the Denver Block. The meeting was called to order by President Keerl. There were present the following members

Messrs. Keerl, Haven, Kelly, Goodale, Relf, Cumming, Heuley, Smith and Hovey ; also several visiting engineers. Wylls A. Hedges, member of the House of Representatives from Fergus County, was also present.

The application of Charles A. Molson for membership, recommended by Messrs Keerl, Heuley and Goodall, having been approved by the Trustees, was read and the Secretary was directed to send out to the members a letter ballot for the same. Ballots for admission to membership were then canvassed by Messrs. Kelly and Relf, tellers. Upon the announcement of the result, the President announced the election of Daniel P. Mumbrue, Charles H. Palmer, Charles W. Mead, Maurice S. Parker and Charles M. Allen as members of the Society.

A. E. Cumming, of the Committee on County Surveyor and Road Laws, reported that both bills, substantially as adopted by the annual meeting, had been introduced in both houses of the legislature, and that several meetings of the legislative committees had been held, but that no final action had yet been taken. It was voted that the committee be continued and requested to take all necessary steps to urge the passage of the two measures.

The regular order of business was suspended, and the Secretary read a paper prepared by E. H. Beckler, honorary member of the Society, upon the location and construction of the United Verde and Pacific Railway, which was constructed under his direction as chief engineer for the Hon. William A. Clark, of Butte, and completed December 1, 1894. The paper was listened to with much interest by all present. It was then referred to the Board of Trustees, who directed the Secretary to arrange for its publication at an early date in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. On motion of Mr. Goodall, a vote of thanks was given to Mr. Beckler for his paper, and the Secretary was directed to inform him that it would be published as soon as possible.

Letters were read from Col. Joseph T. Dodge and others commending the action of the Society in its efforts to obtain some action by the legislature giving a legal definition of a miner's inch. The colonel says: "Your effort is most praiseworthy and is in behalf of good morals as well as social peace and good will"; also commending the action of the Society in beginning a movement for the more "economical expenditure of the road tax of Montana."

The regular order of business was then resumed, and Mr. Cumming, of the Committee on Water Measurement, reported that the proposed act, adopted by the annual meeting, had been presented to both branches of the legislature; that it had passed the Senate and that it is now before the Committee on Irrigation of the House; that the Society's Committee, the President and other members of the Society had several times met with the House Committee, who had expressed a desire to have A. M. Ryon, who made an able address to the Committee of the Whole of the Senate, to meet with them some evening of the coming week to explain more in detail some parts of the act. After a long discussion by all the members present, it was voted that the President be requested to communicate with Mr. Ryon asking him to meet the committee on the evening of February 12th, and to say that his traveling expenses would be paid by the Society.

Mr. Goodall, the committee to whom was referred the annual address of ex-President Haven, reported that he had looked at rooms for permanent headquarters for the Society and recommended room No. 8, Denver Block, for such purpose, and that the "Secretary's desk and other property of the Society be moved to that room as soon as practicable." The report in relation to permanent quarters for the Society was accepted.

It was voted to thank Mr. Cumming and also Mr. Keerl for the use of their offices for the purposes of the Society up to the present time.

The Committee on the DeLacy Memorial was given further time until next meeting to make their report.

F. J. SMITH, *Secretary*.

Civil Engineers' Club of Cleveland.

CASE LIBRARY, CLEVELAND, OHIO, February 12, 1895.—The meeting was called to order at 7.50 by the President. Forty-eight members and visitors were present.

The record of the meeting held on January 8th was read and approved.

The application of Joseph R. Oldham for Active Membership, Axel Hugo Petterson for Corresponding Membership, and Geo. H. Bowler for Associate Membership, were read.

A letter was read from H. F. Coleman, transmitting his resignation as a Corresponding Member.

A letter was read from Mr. Peter Neff, Jr., transmitting his resignation from Active Membership.

The Nominating Committee reported as follows:

Your committee appointed at the last meeting, January 8th, to prepare a list of officers for the ensuing year, begs leave to report the following list of candidates:

President, Augustus Mordecai.

Vice-President, C. W. Wason.

Secretary, F. A. Coburn.

Treasurer, J. C. Wallace.

Librarian, James Ritchie.

First Director, Walter Miller.

Second Director, John L. Culley.

Respectfully submitted,

A. H. PORTER, *Chairman*.

Mr. Richardson moved that a committee be appointed to make any necessary arrangements in the way of fixing up the portion of the Library room which will hereafter be occupied by the Club. Amended by Mr. Searles to refer the matter to the Executive Board. Amendment and original motion were both adopted.

Prof. Howe moved the appointment of a committee of seven to make arrangements for the Annual Banquet. The President appointed on this committee Messrs. A. H. Porter, J. N. Richardson, Prof. C. S. Howe, Frank C. Osborn, M. W. Kingsley, James Ritchie and Alex. E. Brown.

Mr. John L. Culley then gave a brief account of the Cincinnati meeting of the Ohio Society of Surveyors and Civil Engineers.

The tellers, Prof. D. C. Miller and Mr. Harry S. Nelson, announced the result of the ballot on Amendments of Constitution as follows:

Total number of envelopes received		46
Number rejected for non-endorsement	2	
Number rejected not entitled to vote	2	4
	—	—
Number of legal ballots cast		42
		==
	Yes.	No.
Article V, Section 1	34	8
“ V, “ 2	35	7
“ IX, “ 10	37	5

The Amendments were therefore declared adopted.

Col. Jared A. Smith then presented, informally, a paper entitled “ Engineering of Crib Construction as Applied to Harbor Improvements,” which was discussed by Messrs. Culley, C. H. Strong, Richardson, Porter, Geo. M. Ried, Barber, Rawson, Searles and Howe.

President Swasey then gave a brief account of the Appian Way, visited by him on his late trip abroad.

Meeting adjourned at 10 P.M.

FRANK C. OSBORN, *Secretary.*

ASSOCIATION OF ENGINEERING SOCIETIES.

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No. 3.

PROCEEDINGS.

Western Society of Engineers.

The 324th meeting of the society was held in Science Hall, Armour Institute, Chicago, Wednesday evening, February 6, 1895.

Previous to the meeting twenty-one members and guests took dinner together at the Grand Pacific Cafe.

The members and their guests were received at Armour Institute by the Faculty, and under the courteous guidance of the students of the Technical College, visited the various departments of the Institute, after which the meeting was called to order at 8 o'clock, in Science Hall, President Horace E. Horton in the chair and 150 members and guests present.

On motion, the routine business of the evening was dispensed with, and President Gunsaulus, of Armour Institute, welcomed the society to the Institute in the following brief address:

"I have asked your president to allow me just a word in the name of my associates in Armour Institute to convey to you our hearty welcome and to rejoice with those who do rejoice even in the midst of this inclement weather to-night.

"When I was asked to say just a word on behalf of the gentlemen who compose the Faculty of the Institute, who have to do with the science of engineering in its various branches, I felt that it was quite out of my line, and when some gentleman, coming up on the car with me to-night, said: 'I suppose you will certainly be able to welcome the engineers with heartiness, even though it be a very cold evening,' I thought that the expectation was a little large, owing to the fact that I know so little about the subject. I remember that when I came into the Institute and was elaborately discussing with a trustee of my church some of the things that we had put in, the names of machines that I had most recently learned, and therefore was very anxious to pronounce in his hearing, he said to me, 'Look here, Doc, do you know the difference between a dynamo and a motor?' I confess I felt a little puzzled with his question, and was hardly able to answer.

"But I have learned just enough, gentlemen, to appreciate your presence here in Armour Institute, and I assure you that we do understand the

immense value to us of your coming to us to-night, what it means to our students, and what it may mean to all the future of our Institute work.

"It is not necessary, I am sure, for even a minister to be a mechanical or an electrical engineer in order to be conversant with the fact that without practical men close to us we cannot do any thorough work with the young men who give their lives and welfare in our charge.

"I have often been reminded, in meetings of this sort, of the necessities that we used to find in theological seminaries. Now and then a minister who was in the midst of his work came into the seminary, and, being a spiritual engineer, as you men are mostly mechanical, civil or electrical engineers, we found ourselves in the presence of facts that we learned entirely too little about in our common work, as the days went by. It is our effort, here in Armour Institute, to unite the ideal and the practical, to begin with the great facts of science and to come closer to the earth with all its practical problems, and I assure you that the presence of so many men who are actively engaged in engineering gives spinal column and atmosphere to our work such as we could obtain nowhere else.

"Before I took hold of this Institute I was very anxious to find men who would share with me the feeling that nothing is so ideal that it may not be most practical, and that the most scientific training is, after all, ultimately the most practical training in these lines. And I have been fortunate enough, I think, to associate together in this institution men who share these hopes. We are anxious indeed that our young men should be in the closest possible touch with those who are doing, in the world of the present, the things that they are to do in the world of the future.

"This is distinctly a great gift and help to us, and we thank you to-night for your presence, and hope that you will always feel that Armour Institute is at your disposal, every room, every book in our library, that we may give to the Western Society of Engineers for its pleasure, as you shall give to us of your experience and information, is at your command." (Applause.)

The two papers for the evening—Description of the Work and Methods of Construction on the Brighton and Summit Divisions, respectively, of the Chicago Sanitary Drainage Canal—were then read by the authors, Messrs. Alexander E. Kastl and E. R. Shnablen, the engineers in charge on those divisions.

The papers were illustrated by a large number of very fine lantern views of the work, and of the machinery and appliances in use on these divisions of the canal. These views were especially prepared by the Institute, without cost to the society, and were projected by a high power electric lantern, adding very much to the interest of the meeting. The papers are to be published in the "Journal."

There being no discussion of the papers, the meeting adjourned.

The company then repaired to the Department of Domestic Arts and were served with a light lunch, dispersing at a late hour. The first meeting of the society at Armour Institute was an unqualified success, despite the stormy weather.

At a meeting of the Board of Directors, held February 5, 1895, the applications of the following named gentlemen for membership in the society were received and placed on file:

As Members—George Marshall Ames, Grand Rapids, Mich.; A. M. Feldman, Chicago; Charles Linneus Gould, Chicago; Stephen French Hoge, Romeoville, Ill.; John McCalman, Fenton, Mich.; Lauren Bronson Merriam, De Kalb, Ill.; James H. Travis, Chicago; Robert Bruce Wilcox, Chicago.

CHARLES J. RONEY, Secretary.

325th Meeting, March 6, 1895.—The 325th meeting of the society was held in the society's new rooms, 1737 Monadnock Block, Chicago, at 8 P.M., March 6, 1895, President Horton in the chair and about 125 members and guests present.

The reading of the minutes of the previous meeting was dispensed with, President Horton, for the Board of Directors, reporting progress in the management of the affairs of the society, without going into details.

The Secretary reported as follows:

At the meeting of the Board of Directors held March 5, 1895, the following named gentlemen were elected to membership:

As Members—George Marshall Ames, Grand Rapids, Mich.; Charles Linneus Gould and A. M. Feldman, Chicago; Stephen French Hoge, Romeoville, Ill.; John McCalman, Fenton, Mich.; Lauren Bronson Merriam, De Kalb, Ill.; James H. Travis and Robert Bruce Wilcox, Chicago.

The following applications for membership were received and placed on file:

As Members—George M. Basford, Chicago; C. V. Brainard, Kampsville, Ill.; William S. Dawley and Nicholas D. Pound, Chicago; Leonard Sewall Smith, Madison, Wis.; George E. Waldo and Edward Dana Wickes, Chicago.*

As Associates—George Horace Bryant and Charles F. Quincy, both of Chicago.

Bills to the amount of \$188.93 were approved and ordered paid.

The Treasurer reported funds on deposit, March 1, \$1214.52.

Mr. Gerber then read the following report of the Committee on Excursions and Entertainments:

Chicago, March 6, 1895.

Western Society of Engineers.

Gentlemen: The Committee on Excursions and Entertainments for 1894, having finished its work with the ending of the banquet held at the annual meeting, wishes to submit the following report:

The committee arranged for the following entertainments:

August 16—Excursion by steamer on lake to ship yards of the Chicago Ship Building Company on Calumet River, and from there, in the afternoon, to Fort Sheridan and return. This excursion was participated in by 140 persons, members and their families, and from expressions of members from time to time, the committee hopes that it was considered a success.

The next excursion was on the 8th of September to the Drainage Canal by train over the Atchison, Topeka and Santa Fe R. R. The "all earth" sections at the Chicago end of the line, and the "all rock" sections near the other end of the line were visited. The railroad company furnished a special train free of charge and, by the courtesy of Messrs. Gahan & Byrne, a lunch was provided. The entire excursion was without expense to the members, 220 participated in this excursion.

The third excursion was also to the Drainage Canal, the work inspected on this occasion being between Summit and Willow Springs. A special train was this time furnished by the Chicago and Alton R. R. and lunch by Messrs. Griffiths & McDermott. This excursion was also without expense to members. There were 258 present.

The fourth excursion was a trip to the works of the Illinois Steel Company, Iroquois Furnace Company, Chicago Ship Building Company and Morden Frog & Crossing Company. The Baltimore and Ohio R. R. fur-

* At a meeting of the Board of Directors, held March 19, the application of Mr. Charles F. White for membership was received and placed on file.

nished a special train; lunch was provided by the committee, a charge of fifty cents being made to the members. 120 persons were present.

The fifth entertainment arranged for by your committee was the annual banquet, at which there were 111 members and guests.

When your committee was appointed, it was instructed that it should make its arrangements without any expense to the society. Invitations were liberally issued to prominent people of the city for the last three excursions, and a considerable number to the annual banquet. The expense occasioned by these invitations was borne by the committee and defrayed from amounts paid by the members. The committee has the pleasure, therefore, to report to the society that in its management it has not drawn a single cent from the treasury of the society, the committee having this day reimbursed the society for the expense of engrossing five sets of resolutions presented to the railroad companies and the contracting firms who so courteously furnished us with trains and lunches.

The committee also takes pleasure in being able to say that they are not individually out of pocket on account of any of these entertainments. We hope that the work of the committee has been satisfactory to the society, and we now request that the committee be discharged.

The committee wishes to take this opportunity to thank Mr. Appleton, who kindly consented to act as secretary to the committee and pulled the laboring oar.

H. E. HORTON,
E. GERBER,
FERD HALL,
J. J. REYNOLDS.
R. SHAILER, Committee.

The report was accepted, and the committee was discharged with the thanks of the society.

Mr. Strobel read the following report of the Committee on Quarters:*

To the Western Society of Engineers.

The Committee on Quarters respectfully reports that it has secured accommodations for the society on the seventeenth floor of the Monadnock Block, rooms 1736 to 1739, both inclusive.

The Monadnock Block is a first-class office building, fire proof.

A three years' lease has been taken, running from May 1 of this year, with the privilege of possession free of rent until May 1.

The space secured measures 1000 square feet, and is about one-third greater than the space occupied by the society in the Lakeside Building. The rent for this larger space is about the same.

The rate at which these accommodations were secured is about one-third of that usual for like accommodations in first-class office buildings.

The rooms face towards the East, giving a fine view of the lake. These quarters are as free from smoke and dirt as can reasonably be expected in the business quarter of the city.

The rooms are now occupied by the society.

C. L. STROBEL,
T. APPLETON.
CHAS. J. RONEY, Committee.

Chicago, February 6, 1895.

* This report was prepared for presentation at the meeting of February 6, but all routine business of that meeting was dispensed with, and the reading of papers followed.

The report of the committee was accepted and the committee was discharged.

It was voted that the chair appoint a committee of five members as a Committee on Excursions and Entertainments for the year 1895.

It was voted that the Committee on Library, of the past year, be continued. The committee are Messrs. O. Chanute, Fred Davis, John Lundie, Henry M. Sperry and Charles J. Roney.

President Horton announced a special meeting at Armour Institute for March 20, and addressed a few words to the guests of the evening in regard to the society.

The business meeting then adjourned, and the company engaged in conversation and partook of the bountiful lunch provided by a special committee of the Board of Directors, dispersing at a late hour after a thoroughly enjoyable and sociable gathering.

On Saturday afternoon, March 16, 1895, on invitation of Mr. Samuel G. Artingstall, City Engineer, about 75 members and guests visited the new Van Buren street rolling-lift bridge. Every opportunity was afforded for a study of this novel bridge, representatives of the City Engineer's office, and of the contractors, explaining the construction and working of the bridge, which was repeatedly operated for the pleasure of the company. The Metropolitan West Side Elevated Railway Bridge was also visited by invitation of Mr. William Hughes, Assistant Chief Engineer, who, with his assistants, gave much interesting information regarding this bridge.

A special meeting of the society was held at Armour Institute, on Wednesday evening, March 20, 1895, at 8 o'clock, President Horton in the chair and 86 members and guests present.

The President announced as the Committee on Excursions and Entertainments: Messrs. Thomas Appleton, E. Gerber, James J. Reynolds, Ralph Modjeski and George P. Nichols.

Mr. Warren S. Roberts, City Engineer of Bridges, then read his paper—"The Van Buren Street Rolling-lift Bridge," the paper being illustrated by many lantern views. A lantern view of the Tower Bridge of London was then shown, and Mr. Strobel presented some interesting notes in regard to this bridge.

A written discussion of Mr. Roberts' paper, by Mr. W. W. Curtis, was read by Mr. Lincoln Bush, and was followed by oral discussion by Messrs. Goldmark, Hasbrouck, Strobel, Roberts, Bush, Appleton, Nichols, Johnston, Liljencrantz and President Horton, after which the meeting adjourned.

CHARLES J. RONEY, Secretary.

Boston Society of Civil Engineers.

ANNUAL DINNER, March 12, 1895.—The thirteenth annual dinner of the society was served at the Exchange Club, Boston, at 6.30 o'clock P. M. One hundred and sixty-three members and guests were present. President William E. McClintock sat at the head of the table, and the following gentlemen were present as guests of the society; Mr. George S. Morison, president of the American Society of Civil Engineers; Mr. Frank A. Hill, secretary of the State Board of Education; Mr. George G. Crocker, chairman of the Boston Transit Commission; Mr. Osborne Howes, of the Commission on Greater Boston; Mr. Woodward Emery, chairman of the Massachusetts Harbor and Land Commission; Mr. George A. Perkins, chairman of the Massachusetts Highway Commission; Colonel H. G. Prout, editor of the "Railroad Gazette;" the Rev. Thomas Van Ness, Mr.

G. A. Stacey, president, and Mr. J. C. Whitney, secretary of the New England Water-Works Association; Mr. W. L. Dickinson, chairman of the Massachusetts Highway Association; Mr. F. M. Curtis, secretary of the New England Railroad Club, and Mr. F. M. Wakefield, secretary of the Boston Architectural Club.

President McClintock, after a few words of congratulation to the members on the work of the society during the year, introduced Mr. Morison, who humorously admitted that the American Society was the junior of the Boston Society by a few years. "But," he added, "so also is the United States of America the junior of the Commonwealth of Massachusetts by 125 years." He contrasted the local with the national society, and went on to define the characters of the two, the chief distinction between them being, he thought, clearly indicated by their names. He spoke of the convention of the American Society which was held in Boston in June, 1878, and was glad to say that the next convention would be held in Boston in June. At that time the members would wish to see what had been accomplished in Boston during those 17 years. "No city in the country," said he, "holds the advanced position that Boston holds in respect to the development of a water system, a sewerage system and a park system."

The next speaker was Mr. Hill, of the Board of Education, who referred to the numerous "brain Saharas" which all professions must struggle with—the prejudice and ignorance everywhere found—and lauded the wonderful triumphs of the engineering profession. Mr. Crocker spoke in a humorous vein, declining to discuss in detail the subject of rapid transit. His general idea of rapid transit was to start on time, to travel as rapidly as possible and to stop easily.

Mr. Howes narrated pleasantly how his little boy had puzzled him with the question: "If Mr. So-and-So is a civil engineer what is an uncivil engineer?" He then offered an explanation of the use of the word "civil" in that connection. "Civil" is a part of the word "civilization," and civil engineering is the forerunner and promoter of modern civilization.

Colonel Prout, Mr. Emery and the Rev. Mr. Van Ness closed the speaking of the evening.

ANNUAL MEETING, March 20, 1895.—The annual meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield street, Boston, at 7.45 o'clock P. M., President William E. McClintock in the chair. Eighty-nine members and visitors present.

The record of the last meeting was read and approved.

Messrs. William M. Bailey, Arthur Bartlett, Herbert E. Gage, Nathan C. Grover, George H. Hamlin, Henry G. Hunter, Henry A. Nash, Jr., Arthur J. Ober, Arthur G. Pierce and Bertrand T. Wheeler were elected members of the society.

On motion of Mr. Folsom it was voted, "That the thanks of the society be given to our fellow-member, Mr. William H. Bradley, for his very interesting gift of a portrait of the late E. Sylvester Chesbrough, one of the founders and one of the earliest officers of our society, and president of the American Society of Civil Engineers."

On motion of Mr. Manley the sum of \$25.00 was added to the appropriation for the incidental expenses of the last annual dinner.

The annual report of the Board of Government was read by the secretary and accepted.

The annual reports of the secretary and the treasurer were read by these officers and accepted.

The annual report of the Committee on Excursions was read by its chairman, Mr. Winslow, and accepted.

The annual report of the Committee on the Library was read by the librarian and accepted.

Mr. Doane, for the Committee on Permanent Quarters, made a verbal report, explaining what had been done by the committee during the year, and it was accepted.

The Committee on Weights and Measures was given until the next meeting to submit its report.

On motion of Mr. Stearns it was voted to refer to the Board of Government, with full powers, the questions of continuing the several special committees and of the selection of the members thereof.

The secretary read a communication from a Committee on Standard Gauges for Thickness, of the American Society of Mechanical Engineers, requesting the co-operation of this society in the effort to abandon the system of arbitrary gauges and to secure the adoption of a decimal system giving the actual thicknesses and diameters of the pieces. After a short discussion it was voted to refer the communication to the Board of Government, to report back to the society what action was desirable.

Mr. George A. Carpenter presented the report of the committee appointed to prepare a memoir of Mr. Lincoln G. Heywood, and it was read and accepted.

Mr. A. F. Noyes presented the report of the committee to prepare a memoir of Mr. Hiram Nevons, which was also read and accepted.

Mr. Kimball, for the tellers, submitted the result of the letter-ballot for officers.

There being no election for president and librarian by letter-ballot, the meeting proceeded to choose these officers from the two candidates having the highest number of letter-ballots.

As the result of the letter-ballots and choice of the meeting, the president announced the following officers elected:—

President, ALBERT F. NOYES.

Vice-president (for two years) DEXTER BRACKETT.

Secretary, S. EVERETT TINKHAM.

Treasurer, EDWARD W. HOWE.

Librarian, FRANK L. LOCKE.

Director (for two years), RICHARD A. HALE.

The president called attention to the fact that at the close of the meeting, one of our members, Mr. Henry Manley, would retire from the Board of Government after fifteen years of continuous service, and spoke in very complimentary terms of the faithful manner in which Mr. Manley had served the society as treasurer, president and director. In response to the hearty applause which followed the remarks of the president, Mr. Manley thanked the members for this expression of their appreciation of his efforts in the interest of the society. He spoke of the pleasure his connection with the society had always given him, and of the pride he took in its prosperity, and closed by extending to the society his best wishes for its continued success.

President William E. McClintock then delivered his annual address as follows:

TO THE MEMBERS OF THE BOSTON SOCIETY:

The most casual observer cannot fail to note the great changes in the profession of the civil engineer since the organization of the Boston Society 47 years ago. In the early years of our society, railroads were in their infancy, street railways were not deemed of sufficient importance to call for the services of an engineer, sanitation and water supply were prac-

tically unknown factors, electricity was but a plaything, its real commercial value not even being dreamed of by the most visionary of dreamers, road building was one of the undiscovered arts, as far as this country was concerned, iron and steel were used in the most primitive manner, and were hardly thought of in connection with bridges or buildings, and a thousand and one things which seem to us but everyday facts were then in the great to be. There was not seen in those days the bustle of today. The few people who traveled were in no hurry, and, if they were, it availed them nothing. Mails were sent and received, but a few days more or less in their transmission were taken as natural and unavoidable delays, and caused no comment. Freight was in many instances delivered weeks after it was expected, the telegraph was nothing more than a lively infant, and the man who dared suggest the possibility of sending messages across the ocean would have been considered a fit subject for a lunatic asylum, while he who turned his face to the wall and repeated his "Hello," "Yes," "No," "All right," with the claim that he was holding conversation with parties hundreds of miles away, might have been almost burned at the stake as one being in league with the powers of darkness.

Our houses and business blocks were simple and plain, with but little artistic skill in plan or execution. Our streets were roughly paved and but dimly lighted at night. Our houses and public buildings were lighted for the most part with the tallow candle or the whale oil lamp, which tended to deepen the gloom of night. As one looks about him and stops to think, he will gradually realize the great changes which have taken place during the few years which have elapsed since the founding of this society, and the civil engineer cannot fail to have a certain amount of pride when he feels that to the members of this society and of kindred societies in different parts of the world has fallen the duty of planning and directing the works which have wrought such a change in the social conditions of the world. Ours is a work which demands a steady hand and an active brain, a power to plan and an ability to change the original plans to meet the unexpected, which is sure to happen in engineering works; and, to be successful, an engineer must keep pace with the times and not repeat a blunder which has at any time been shown to be such.

History and law, mechanics and mathematics, tact and patience, are all needed, if one would succeed, and when one does succeed it is a great surprise to see on what slight foundation his success is based. If called upon to give the first requisite of a civil engineer, I should name honesty. He is not counsel to argue for his client, but rather judge and jury to decide what is right, regardless of persons, and, looked at in this light, he must have a clear head, and an honest, unbiased judgment. This brings up the question whether an honest, unbiased judgment, in connection with engineering skill and experience, is a merchantable commodity, to be sold to the highest bidder. Unquestionably it is not, and the engineer who countenances such action injures not only himself but likewise the whole profession. The astronomer recognizes the personal equation of his fellow observers, and by careful comparison reduces their observations to one standard. The engineer who sells his judgment to the highest bidder must sooner or later establish a personal equation of honesty, and competition will inevitably lower the standard as it will demand that the study be made at as low a cost of labor as possible, while the expression "It is good enough for the money" will surely be thought, if it is not expressed.

I am glad the Boston Society is broad and liberal in its requirements as to membership admission. The local societies are the home and school, the means of closer fellowship and intermingling of ideas. It is by means of these societies that the old jealousies have been largely broken down,

and a brotherly feeling has taken their place, so that each engineer feels to rejoice with the successes of his fellow-engineer. I say largely broken down, as it is with regret that we still observe isolated cases where one attempts to elevate himself by pulling his brother down. If we expect to place engineering among the learned professions, education and ability must be accompanied by dignity, and the policy of advertising, except by card, or that of writing and visiting parties with the purpose of soliciting the privilege of planning and supervising large works must be discontinued, and such practices should be frowned down by every engineer, as would be the case in the practice of law or medicine. Possibly it may be a misfortune that the civil engineer has no stated code of ethics, or schedule of prices. As a result it often happens that roving committees find one engineer who unconsciously gives figures lower than another for performing the same work, and thus unwittingly places himself in competition. This difference in price may result from increased facilities on the one hand, or it may arise from a desire to obtain the work at all hazards, and at any price. If the difference results from the cause first named, no fault can be found; but if, on the contrary, the last named reason applies, it not only demeans the guilty party, but it also belittles the profession and tends to bring the engineer into disrepute.

The society has just passed through a very successful year, the membership having been increased by the addition of thirty-two new names, bringing the total up to 354. The regular meetings have been well attended, the papers have been carefully prepared, and of unusual interest. The excursions to local points of interest, or to works in progress, have been of value to the many who attended them, and the informal suppers before the regular monthly meetings have increased in popularity, and are a great factor in bringing our members together and making them better acquainted, one with the other. The weekly informal meetings in the library, with descriptions and discussions of work being done, have been so well attended that the capacity of the room has been sorely taxed, and the question of enlarged headquarters has been unexpectedly and forcibly brought before the society. The attendance at these informal talks has been nearly double the attendance at the regular monthly meetings of fifteen years ago, and their continuance in more commodious quarters should be the early aim of the society. Many of our members do not realize that the permanent fund of the society is growing quite rapidly, and that within the past fourteen years we have succeeded in saving, from our regular income, over \$6000. This sum may seem small, but one has only to look at the Franklin fund, which, without any increment other than the interest, increased from about \$5000 to \$375,000 in a little over one hundred years, and he will see that with the honest conscientious attention which our fund receives from our treasurer, we may expect it to increase so that the younger members may reasonably expect to carry on the work of the society in a home of its own. The kindly forethought of one of our members in subscribing a liberal amount for the establishment of a fund for permanent headquarters, has opened up a new line of thought in this direction, and I trust that the beginning thus made will spur others on in the same direction, and induce them also to build for the future.

The general depression of business has more or less affected engineering works, although many important schemes have been started, or reported on, during the year, and some extensive works have been brought to a successful termination. Notably amongst the works which have been started may be mentioned the Commonwealth's action in regard to parks and State Highways. Amongst the reports which have been made reference may be made to the Charles River dam and the Metropolitan

Water Supply. The activity in steam railroad work has mostly been confined to additions and improvements, such as can be seen at the new Union Station, Boston. The elimination of grade crossings at Mystic Wharf, Boston; the Roxbury crossing, the Brockton crossings and other like work. The electric railways have ceased to be a purely city institution. They are now reaching out in every direction, and are sure to be a competitor with the steam railroads. In the laying out of these railroads the engineer should have in mind the perplexing problem of grade crossings, as illustrated by the steam railroads, and he should do all in his power to prevent, if possible, a repetition of this great evil. The planning and execution of both public and private work are being more and more entrusted to the engineer. Almost every city, and some of the larger towns, have a regularly elected engineer to look after the public works.

No city or town would for a moment consider the sewerage or water problem without a careful study and report by a competent engineer, and he is not only called upon to plan work, but he is also required to advise on ways and means, and in various other directions. The old fallacy that an engineer cannot sit as a member of a deliberative commission seems to have been broken down, in our State at least, by the appointment of four members of our society on as many different and important commissions. We must bear in mind that we are what we make ourselves, and it remains for us to act in such a conservative, careful and dignified manner as will demand the confidence of our clients and the respect of the public at large.

In closing I wish to thank you as a society for the great honor you have conferred upon me by electing me to serve as your president during the period just past. I can assure you that I deem it one of the greatest honor of my life, and as I step back into the ranks, it will be with renewed effort to do everything within my power to bring honor and success to our society.

At the close of the formal address, Mr. McClintock had thrown upon the screen a large number of lantern views showing the work done by the Massachusetts Highway Commission in the construction of State roads. Views were also shown of the roads and other objects of interest in Bermuda which Mr. McClintock had recently visited.

(Adjourned).

S. E. TINKHAM,
Secretary.

Annual Report of the Board of Government for the Year 1894-1895.

In compliance with the provisions of the Constitution, the Board of Government submits the following as its annual report for the year ending March 20, 1895:

We congratulate the members of the Society upon the very prosperous year which is now closed. A larger number of names has been added to our list of members than in any previous year, the attendance at the regular meetings has been greater, our annual dinner brought together more of our members than were ever assembled before, and our financial condition was never better.

During the year ten regular meetings have been held, and the thirteenth annual dinner of the Society took place on March 12, 1895. The total attendance at the regular meetings was 896, an average of 90, the smallest attendance at any meeting being 40 and the largest 121. The attendance at the annual dinner was 163, a gain of nearly one-third over the largest attendance at any previous dinner.

The following papers and discussions have been given at the regular meetings:

March, 1894. New Formula for Calculating the Flow of Water in Pipes and Channels, by W. E. Foss. Account of Driven Wells in Lowell, by George Bowers.

April, 1894. Street Grades and Intersections, by William B. Fuller. Account of Welding Electrically the Tracks of the West End Street Railway, by A. L. Plimpton.

May, 1894. Improvements of the Charles River, by F. P. Stearns, with discussion (illustrated).

June, 1894. Cement Joints for Sewer Pipes, by F. C. Coffin. Bicycle Track at Waltham, by W. E. McClintock.

September, 1894. Testing Materials at Massachusetts Institute of Technology, by Gaetano Lanza.

October, 1894. Cableways, by Spencer Miller (illustrated).

November, 1894. European Water Supplies, by Allen Hazen. Lake Vyrnwy Water Supply, by T. M. Drown.

December, 1894. Memoir of C. W. S. Seymour. Abolition of Grade Crossings, by J. W. Rollins, Jr.

January, 1895. Use of Steel in Large Buildings, by C. T. Purdy (illustrated).

February, 1895. Proposed Reservoirs for the Storage of the Flood Waters of the Nile, by Cope Whitehouse (illustrated).

At the last annual meeting the total membership of the Society was 322, of which 315 were members, 5 honorary members and 2 associates. During the past year we have lost 9 members—5 by death, 1 by resignation, 1 by transfer to the Engineer's Club of St. Louis and 2 by forfeiture for non-payment of dues. There have been added to the Society during the year 41 members—37 by election, and 4 who had resigned or forfeited membership, have been reinstated. The net gain in membership has been therefore 32.

The present membership of the Society consists of 2 associates, 4 honorary members and 348 members, a total of 354. This number entitles the Society to a fourth member on the Board of Managers of the Association of Engineering Societies.

The record of deaths for the year among our members is as follows: Hiram Nevons, who died May 27, 1894; Forrest L. Libbey, who died July 21, 1894; Phineas Ball, who died December 19, 1894, and Lincoln C. Haywood, who died January 12, 1895. We have also lost one of our honorary members, Franklin Darracott, who joined the Society at its organization in 1848 and died January 24, 1895.

The plan inaugurated last year of holding informal meetings in our library on other Wednesday evenings than those assigned to the regular monthly meetings, has been continued during the winter months. The only difficulty experienced so far in arranging these meetings has been in the way of accommodations. At some of these meetings the attendance has exceeded thirty persons, and our library is wholly inadequate for such a gathering. As a matter of record, a list of the informal meetings is here given, with the subjects discussed.

January 31, 1894. Sewerage of Newton, by H. D. Woods.

February, 1894. Work of the Metropolitan Sewerage Commission, by Charles H. Swan.

February 28, 1894. Work of the Boston Sewer Department, by E. S. Dorr.

March 14, 1894. Work at Dam 6, Boston Water Works, by N. S. Brock.

- March 28, 1894. Brookline Water Works, by F. F. Forbes.
 April 4, 1894. Construction Work of the Boston and Albany Railroad, by William Parker.
 April 11, 1894. Boston Public Parks, by E. W. Howe.
 April 25, 1894. Details and Methods of Work on Massachusetts State Survey, by E. E. Pierce.
 May 2, 1894. Oxidation of Structural Iron by Electrolytic and Other Means, by J. H. Stanwood.
 May 9, 1894. Work of the Harbor and Land Commissioners, by F. W. Hodgdon.
 November 28, 1894. City Engineering at Duluth, Minn., by William B. Fuller.
 December 5, 1894. Coinage, Weights, Measures and Trigonometric Tables, by Fred Brooks.
 December 12, 1894. Recent Water Works Construction, by F. L. Fuller.
 January 2, 1895. The Present Method of Laying Out Streets in Boston, by F. O. Whitney and F. M. Miner.
 January 9, 1895. Graphical Computation as Applied to Engineering Problems, by Freeman C. Coffin.
 January 16, 1895. Notes on Power Production, by Robert S. Hale.
 January 30, 1895. Lighthouse Foundations, by Edward P. Adams.
 February 6, 1895. Sewer Construction in Malden, by G. A. Wetherbee.
 February 13, 1895. Municipal Work in Brookline and Vicinity, by A. H. French.
 February 27, 1895. Coal Handling Appliances for Supplying Locomotives, by J. P. Snow.
 March 6, 1895. Municipal Work in Cambridge, by L. M. Hastings.
 The report of the Treasurer shows a net gain of \$791.42 in the funds of the Society during the past year.
 One of our ex-presidents, Mr. Desmond Fitzgerald, has subscribed a liberal amount to form the nucleus of a fund for permanent headquarters. This act demands more than an acknowledgment with thanks, as it opens up a new field of action. Without any recommendation as to methods, the Board of Government would suggest that the Society, at an early date, take some definite action towards adding to this fund.

Respectfully submitted, for the Board of Government,

WILLIAM E. McCLINTOCK,
 President.

Abstract of the Treasurer's and Secretary's Reports for the Financial Year 1894-1895.

CURRENT FUND.

RECEIPTS.

Dues of new members.....	\$181.50
Dues of resident members for 1893-94, 2 at \$7.....	14.00
Dues of resident members for 1894-95, 244 at \$7.....	1708.00
Dues of non-resident members for 1893-94	5.00
Dues of non-resident members for 1894-95, 70 at \$4.....	280.00
Dues of non-resident members for 1894-95	1.00
Dues of non-resident members for 1895-96, 3 at \$4.....	12.00
Sales of Journal.....	4.30

Rent of office.....	150.00
Interest on deposits.....	1.43
Cash at beginning of year.....	131.68
	<hr/> \$2,488.91

EXPENDITURES.

Association of Engineering Societies.....	\$1150.75
Rent	500.00
Printing, postage and stationery.....	292.49
Periodicals and binding.....	98.38
Expenses at meetings, stenographer and lantern	48.00
Expenses at special meeting.....	6.25
Secretary's salary.....	200.00
Gas	4.10
Annual dinner of 1894.....	32.00
Cash on hand.....	156.94
	<hr/> \$2,488.91

PERMANENT FUND.

RECEIPTS.

Thirty-seven entrance fees.....	\$370.00
Interest and dividends.....	161.32
Share of Merchants' Co-operative Bank, retired	88.54
World's Fair Headquarters Fund.....	54.40
Subscription to Building Fund.....	50.00
Payment of real estate mortgage.....	800.00
Cash at beginning of year.....	27.55
	<hr/> \$1,551.81

EXPENDITURES.

Due in shares in Merchants' Co-operative Bank.....	\$300.00
New shares in Merchants' Co-operative Bank.....	61.42
Cash on hand, uninvested.....	1190.39
	<hr/> \$1,551.81

SCHEDULE OF FUNDS OF SOCIETY ON MARCH 20, 1895.

One Republican Valley Railroad bond (par value).....	\$600.00
Nine shares C., B. and Q. R. R. stock (par value).....	900.00
Mortgage on real estate.....	1000.00
Twenty-five shares Merchants' Co-operative Bank.....	2175.17
Cash on hand, Permanent Fund.....	1190.39
Cash on hand, Current Fund.....	156.94
	<hr/> \$6,022.50
Schedule presented last annual meeting	5,231.08
	<hr/>
Increase during the year.....	\$791.42

Report of the Committee on the Library.

There seems to be but little that the Library Committee can say in the way of a report, but it may be well to mention one or two matters: First, to emphasize the fact of the space for books being so cramped, there being insufficient room even to place the books upon the shelves, to say nothing of arranging them in proper form. It is utterly impossible to find room for the new accessions under the present arrangements; and,

while temporary expedients might be adopted, it would hardly be wise to spend much money in that way when more permanent quarters are in view.

The number of books has increased more rapidly this year than in any previous year, and especially is this true of the more valuable publications of the day.

It is to be hoped, and we earnestly request, that any member of the Society who directly or indirectly publishes anything having the slightest engineering interest, or has any such publications of others brought to his notice, will see that a copy is placed on the shelves of the Society, or, where unable to obtain them themselves, will notify either the Librarian or the Secretary in regard to the matter, thus assisting materially to increase the value of the library.

The use of the library has changed but little during the past year, members finding it rather difficult to get desired information from the shelves on account of the crowded quarters. However, with proper surroundings and a full catalogue, there is no doubt that its use can be greatly extended.

The present system of taking out books is exceedingly faulty, and, but for the thoughtfulness of the members, there would be a large number lost annually. It seems impossible to change this, as we are now situated, but it is earnestly hoped that in the near future a catalogue and a better system of distribution can be obtained.

Until new or more permanent quarters have been procured the Committee cannot make any specific recommendations regarding equipment or operation, but they earnestly hope that no stone will be left unturned to provide proper accommodations at as early a date as possible.

For the Committee on the Library.

HENRY F. BRYANT,

Librarian.

March 20, 1895.

Report of the Excursion Committee.

The report of the Excursion Committee of the Boston Society of Civil Engineers is herewith submitted.

During the year the Committee has provided seven excursions and will, according to custom, provide one more, that for April, 1895. The trip for April, 1894, provided by the previous Committee, was to the works of the Curtis-Davis Soap Company, in Cambridge, and owing to the fact that it immediately preceded a holiday, there were but four persons present. In May a trip was taken to the new Leavitt Pump, at Chestnut Hill, Brighton, also to the force main connecting the pump with the reservoir. Thirty members were present. The June excursion was omitted on account of the New England Water Works Convention.

In September a trip was taken to the new dam, No. 5, now in process of construction by the city of Boston, and there were 52 present.

In October the Deer Island outfall sewer of the Metropolitan System was visited, also the Moon Island Works of the Boston Sewerage System. Seventy-five attended this excursion.

In November a visit was made to various points of interest in Lowell, 42 being present.

In December the excursion was omitted, and in January the East Boston Tunnel of the Boston, Revere Beach and Lynn Railroad was inspected by 42 members.

The most popular trip of the year was made in February to the

Charlestown Navy Yard, to see especially the new ram Katahdin. Other points of interest in the Yard were visited, 110 members and friends being present.

In March the garbage reduction works of the New England Construction Company, on Gibson street, Dorchester, were visited, 55 members present.

The Committee desires to express to many of our members its appreciation of the many courtesies extended and the co-operation cheerfully given in order that our excursions might be successful.

For the Committee,

FREDERIC I. WINSLOW,

March 20, 1895.

Chairman.

HIRAM NEVONS.

A MEMOIR.

By R. C. P. Coggeshall, Albert F. Noyes and Dexter Brackett, Committee of the Boston Society of Civil Engineers.

(Read March 20, 1895.)

Hiram Nevons was born at New Gloucester, Me., April 5th, 1836. His father was a farmer and he lived at home until he was sixteen years old, when he went to Portland to learn the carpenter's trade. The next year we find him employed by a firm of ship builders at Freeport, Me., where he remained four years. He then came to Boston and entered the service of Gore, Rose & Co., municipal and railroad contractors, who soon placed him in charge of their paving contracts with the city of Cambridge. Although but twenty-one years of age, he had already demonstrated a rare ability in the leading and management of workmen, and his services were deeply appreciated by his employers. Owing to the panic of 1857, business soon became very much depressed, and during the following winter we find Mr. Nevons at Mobile, Ala., where, in company with two other Northern men, he contracted to do a large amount of work on a mail steamer then building there. The following spring he returned to Cambridge and re-entered the service of his former employers, Gore, Rose & Co., remaining continuously with them until the spring of 1862, when, under the pressure of war time, nearly all work on municipal improvements ceased.

He then returned to Freeport, Me., where, in September, 1862, he enlisted in the Twenty-fifth Regiment of Maine Volunteers. He remained in the service until the regiment was mustered out, in July, 1864. The following three years he was engaged in ship building at Yarmouth and Freeport, Me., and at Cleveland, O. In September, 1867, he returned to Cambridge and followed the business of paving for the next ten years, eight in the employ of Gore & Co. and the remainder on his own account.

On May 8, 1877, he was unanimously chosen to be superintendent of the Cambridge Water Works, which position he ably filled until the day of his death.

It was with great reluctance that Mr. Nevons accepted this position, feeling that he could not command the requisite training in hydraulic engineering, but no mistake in the selection of a superintendent was made by the Cambridge Water Board, for he applied himself with characteristic energy and persistency to his new duties and to studies connected therewith, and soon became well informed upon all matters pertaining to water works construction and maintenance, and his opinions commanded the respect of his large circle of acquaintance among water works officials.

During the seventeen years covered by his administration he occupied an important part in the development of the many improvements which have been made to the Cambridge Water System. The additional supply from Stony Brook has been constructed and Fresh Pond has been deepened in its shallow parts. Its shores have been ripped, and girdled by a wide and attractive drive, and its neighborhood has been converted into a fine park. Other extensive improvements were being made at the time of Mr. Nevons' death. Through all these years Mr. Nevons has modestly attended to his various duties in the most faithful manner. He always proved himself to be a highly satisfactory leader of the men under his charge, and has always retained the confidence of his fellow citizens.

He married an estimable lady of Freeport, Me., in 1859, by whom he had four children, all of whom are living.

He was one of the most widely known members of the Water Works fraternity of New England, and was a member of many societies. Among these may be named in the Masonic Fraternity, the Grand Army of the Republic, the Boston Society of Civil Engineers, the American and the New England Water Works Associations, the Citizens' Trade Union, the Cambridge Club, and others. In all of these he took an active interest and was an honored and beloved member.

He died at his home in Cambridge, Mass., on May 17, 1894, after several weeks of great suffering.

A fitting testimonial to his work and character was offered in the form of resolutions passed by the Cambridge City Council, and the Cambridge Water Board.

He joined the Boston Society of Civil Engineers June 19, 1889, and while, on account of his exacting official duties, he was not permitted to take an active part in its work, he took a great personal interest in the work of the Society and continued his membership during his life. As a man and true christian citizen, he was held in high esteem by all who knew him; as a friend and associate, he was an intelligent, genial, agreeable and thoroughly companionable man.

LINCOLN C. HEYWOOD.

A MEMOIR.

By George A. Carpenter and Morris Knowles, Committee of the Boston Society of Civil Engineers.

(Read March 20, 1895.)

Lincoln Crawford Heywood, youngest son of George and Mary (Reed) Crawford, was born in Pawtucket, R. I., September 29, 1868. Upon the death of his mother he went to live with his aunt, Mrs. Charles Heywood, whose husband was then superintendent of the Boston and Fitchburg Railroad. His early education was received in the public schools of Boston, which city was the home of his adopted parents.

After the death of Mr. Charles Heywood, in 1884, the family removed to Pawtucket, R. I., and the course of study was continued there in the High School. The young man was graduated with the class of 1886, and, with a number of his classmates, entered Brown University in the fall, remaining as a member of the class of 1890 for three years. During this time he prepared himself for that branch of work in which he was ever after deeply interested, and by diligent and conscientious labors he was able in 1889 to enter the third-year class of the Massachusetts Institute of

Technology. He was graduated with this class in 1891, receiving the degree of Bachelor of Science in the Department of Civil Engineering. The title of his graduating thesis was: "A Plan for Widening the Stone Highway Bridge at Pawtucket, R. I.," and this, together with his other school work, showed the careful and painstaking habits which have characterized all of his later efforts.

Upon leaving school Mr. Heywood was engaged by the Interstate Street Railway Company as their engineer, and in accordance with his plans and under his supervision their large system was built. In July, 1893, he severed his connection with the Interstate Company to accept the position of engineer of the town of Lincoln, R. I., which had been tendered him. He was re-elected in 1894, and held this office at the time of his death.

One of the most important problems encountered in this last position was the design of a sewerage system for a certain section of the town which had long been in need of sewers, but up to this time many difficulties had arisen to prevent their construction. The plan suggested by Mr. Heywood proposed intermittent filtration as the method of disposal. This received the approval of the town authorities, and money was appropriated for the construction of the system, upon which work he was engaged at the time of his last sickness. He desired as well to bring the sewers of the different sections of the town into one complete and harmonious system, and had taken steps to reach this beneficial result.

Mr. Heywood was also much interested in, and had worked upon, a set of assessor's maps of the town. It was his intention to establish and locate all important points by a system of co-ordinates referred to and connected with the United States Coast and Geodetic Survey.

On December 15, 1892, Mr. Heywood was united in marriage to Edith, only daughter of Bela P. Clapp, of Pawtucket, and beside his wife a little daughter remains to mourn his loss.

He was associated with the Delta Upsilon Fraternity, being a charter member of the Brown University Chapter. He was also a member of the Union Lodge, No. 10, A. F. and A. M., and of the Pawtucket Royal Arch, Chapter No. 4.

Mr. Heywood was taken ill the last of December with that dread disease, typhoid fever, which he, in common with many other engineers, through the agency of pure water supplies and proper sewerage systems, had been striving to render less dangerous to the community and less likely to become epidemic in thickly settled districts. He died January 12 1895, being mourned by a loving family and a large circle of friends.

Mr. Heywood became a member of the Boston Society of Civil Engineers May 20, 1894. Although cut off at an early age, he yet leaves behind an example of earnest, thorough and conscientious devotion to the work of the profession, an example by which we may all profit.

GEORGE A. CARPENTER,
MORRIS KNOWLES,
Committee.

Civil Engineers' Club of Cleveland.

ANNUAL MEETING.

CASE LIBRARY, March 12, 1895.—The meeting was called to order at 8 o'clock P. M. by the President. Forty-three members and visitors were present.

The record of the meeting held on February 12 was read and approved.

A verbal report from the Banquet Committee was presented by Mr. Richardson, and also by Professor Howe. The annual reports of the secretary and treasurer were then read, and it was moved and carried that the reports be accepted and placed on file. The annual report of the librarian was then presented, which was also accepted and ordered placed on file. The librarian, in concluding his report, offered the following resolution, which was unanimously adopted:

"Resolved, That the Civil Engineers' Club of Cleveland, wishing to signify their appreciation of the labors of Chairman J. B. Johnson and Secretary J. C. Trautwine in advancing the interests of the Association of Engineering Societies, and in improving the journal of the association, hereby extend to the gentlemen named, a unanimous vote of thanks."

A unanimous vote of thanks was tendered Mr. Ambrose Swasey for the beautiful photograph, representing the bridge and castle of St. Angelo, which he had presented to the club.

A report from the Program Committee was presented by the chairman, E. C. Cooke, which report was accepted and ordered placed on file.

President Swasey then read the annual address, entitled "The Specialist in Engineering." See appendix.

The Secretary then read the reports of the tellers appointed to canvass the ballot for members and officers. Joseph Rogers Oldham elected to active membership. George Herbert Bowler elected to associate membership. Axel Hugo Petterson elected to corresponding membership.

The following were elected to serve as officers for the coming year:

For president, Augustus Mordecai.

For vice-president, Charles W. Wason.

For secretary, F. A. Coburn.

For treasurer, Jome C. Wallace.

For librarian, James Ritchie.

For first director, Walter Miller.

For second director, John L. Culley.

After some short speeches by the newly-elected officers, it was moved by Mr. Mordecai that a vote of thanks be tendered the retiring officers of the club. The motion was unanimously carried.

President Swasey then extended his thanks to the vice-president and secretary of the club, as well as the other officers, for the assistance and support which they had given him throughout his term as president.

The **meeting** adjourned at 9.30 o'clock.

FRANK C. OSBORN,
Secretary.

APPENDIX.

THE SPECIALIST IN ENGINEERING.

ANNUAL ADDRESS OF PRESIDENT AMBROSE SWASEY.

The many difficult and seemingly insurmountable problems in engineering and construction, which have been solved in ancient and modern times, serve as guide posts clearly pointing to the most direct road by which the engineer of to-day may reach his destination. Yet there are many new problems constantly presenting themselves, whose perplexing complications call forth the engineer's thorough knowledge of what has been done, and his skill and ability to devise new ways and means for meeting these new conditions. The many crowded technical and scientific schools throughout this country, where thousands of our brightest young men are

being educated and trained in the various departments, show conclusively that America is awake to the fact that more will be demanded of the rising generation, and that they will be required to undertake the most difficult engineering works. Those who, when young, had not these privileges, but were obliged to study early and late in order to gain the knowledge which is comparatively so easily acquired in these modern schools, so splendidly equipped with every appliance for demonstrating the practical as well as the theoretical side of engineering, can truly appreciate the great advantage they are to the young men who honestly desire a scientific education.

And to what grander and nobler purpose can wealth be devoted than to such practical institutions as Peter Cooper and hundreds of others throughout this country have endowed and equipped? Now, more than ever before, men realize that money thus donated is not spent, but transferred and transformed into active minds, trained in their especial lines of work, upon whom the engineering and scientific achievements of the future must depend.

The engineering societies throughout the country are to the engineers of to-day what the technical schools are to the future. The members of these societies, being men of experience and of similar professions, realize the great benefits derived from attending the sessions, where they may come in contact with those who are working in the same lines, and, although busy men, they travel to distant points of the country in order that they may take part in the discussion of subjects in which they are especially interested, or listen to the advice and experience of others. The increasing numbers and influence of these societies, whose transactions represent the most modern thought and practice, testify to their great value in the education and advancement of the engineer.

The few societies, which, like our own, have among their memberships civil, mechanical and electrical engineers, architects and scientists, and before which are presented papers upon the correlated subjects peculiar to these several classes, provide, for their members, a variety of interest to all. At these meetings we learn of the many types of bridges in use, of the great steamships and of the engines that propel them, of the long and difficult railroad tunnels and trestles, of the generators and transmitters of electrical energy, and of the construction of our great modern buildings; or the scientist tells us of his investigations, of the thought and care that had to be taken at every step of the process, of the minute and subtle quantities with which he had to deal, and he then gives us the result of his research, which was gained only after years of patient toil. Few, perhaps, fully understand the difficulties which he encountered, or appreciate the benefit of the result to the cause of science, yet all are intensely interested in his work and may learn the lesson of accuracy, of the necessity of attention to the smallest detail, and, most important of all, of perseverance. And so with all the subjects that are presented at these meetings. We may learn from each much that will aid us, and we cannot fail to see that the greatest achievements have been won by those who have devoted themselves to a special line of work.

When we visit the interesting city of Florence and see that wonderful statue of David, the admiration of the world, chiselled by Michael Angelo's own hands from an abandoned block of marble, and then enter the Sistine Chapel at Rome and look with amazement at his ceiling frescoes, which are said to excel even those of Raphael, and then retrace our steps and stand beneath the great dome of St. Peter's, which he also designed, and which is acknowledged to be one of the grandest examples of architecture, we feel that to one man at least have been given especial powers by which he

could excel in these great arts, sculpture, painting, architecture and engineering. But the world waited many years for a Michael Angelo, and it has not yet seen another. Few can expect to accomplish what he did, for when we call to mind the works of the great painters, Raphael, Titian and Rubens, or of the sculptors, Canova and Thorwaldsen, or of the architects, Giotto and Brunelleschi, we find that these men won distinction in a single art, although, no doubt, they were ambitious to excel in others.

When we visit the city of Antwerp and study the lines and proportions of the arch or gateway designed by Rubens, and then turn to his most famous paintings in the Cathedral near by, we can but wish that he had continued to use his brush, and had left the designing of the arch to such an architect as he who, one hundred years before, constructed the beautiful lacework tower of that Cathedral. And the same principle holds true in our day. The men who have been foremost in science, in art, in architecture, and in engineering, are those who have given their life work to a single calling or profession.

The beautiful grounds and buildings of the Columbian Exposition formed a noted example of the work of specialists; architects, civil, hydraulic, landscape, mechanical, electrical engineers, scientists, sculptors and artists, each having experience and a thorough knowledge of his own particular department, like trained soldiers, under the direction of an efficient leader, went forward and completed this great work, the result of which we all know. It could not have been otherwise, because it was not the work of one, but the work of many. The grand municipal and mercantile buildings which are now erected so quickly in our great cities, are composite, not only because they are built of different materials, but because they are built by different professions. The architect studies the requirements, lays out the plan, and gives to it expression. The scientist tests the steel for the phosphorus and carbon, and determines the strength and quality of the cement. The civil engineer constructs the foundations and designs the trusses, while the mechanical and electrical engineers attend to the problems of heating, ventilating and lighting, and that of carrying its occupants from floor to floor.

Although a Hunt may design the palatial residences of Newport or give character and grand proportion to the Administration Building, whose dome glittered both by day and by night, yet he called to his assistance an engineer to work out the details of construction, and a sculptor to model the statuary that adorned it. This magnificent structure, when completed, was their combined work, yet it added new laurels to the fame of the architect, and to that of the sculptor and engineer as well. This shows only that the greater the success of the undertaking, the greater the credit to all who take part in the work, and that the architect or engineer who attempts to do the work of others, in order that he may take the entire credit to himself, generally fails in all.

Apparently some are not yet aware that the day of the Universal Engineer, who claims to have a thorough knowledge of all branches of engineering, is past. The high character of the work that is being done throughout the country shows conclusively that it is not the Universal Engineer, but the experienced specialist, who has charge of it. This division of labor in engineering and construction means, more public improvements, more convenient and architectural buildings, better equipped railroads, safer and faster ships, machinery of improved design, and bridges not only substantial, but architectural. In the new Tower Bridge of London, the iron work which sustains the loads is encased in most exquisite stonework for architectural effect, after the manner of our best build-

ings of to-day. This bridge has been severely criticised because of its cost and because it does not represent upon the outside its true construction, yet no doubt, in years to come, it will be looked upon as one of the finest examples of architectural engineering of this age.

We have already done much in this country towards making our public works more ornamental. The beautiful Washington Bridge, so much admired by all, shows our high appreciation of the artistic as well as the useful, and in the future more will be required of the engineer in this direction than ever before.

The old millwright, of the first half of this century, had to construct alone the dam across the river, to hew the logs, and erect the mill, to shape the teeth of the wooden cog wheels, to turn the bearings of the square shafting, and to pick the flinty stones for grinding the grain. If he, like Rip Van Winkle, could now awake, he would find that not only the mountain trees have grown taller and the familiar faces gone, but that his work has been divided between many professions, and that the progress of civilization has so leavened these that many of them have in turn been subdivided, and that, as a consequence, the leaky wooden dam has been replaced by one of solid masonry, the huge creaking overshot water wheel has been taken down in order that the spinning steel turbine might do its work, and that there is left of the mill or machinery but little that he can recognize. Even the old millstones have been taken out and used for steps, while the grain is passing with lightning speed between fluted iron rollers. He finds, in addition to these changes, that, in order to meet the ever-increasing demands of our modern civilization, larger and swifter rivers have been controlled, until the great Niagara has been harnessed to furnish power for heat, light and manufacturing, not only within the sound of its own roar, but by means of threads of copper to great cities many miles away. No wonder the world seems strange to him and that he wishes to return to sleep. Should he awake in the middle of the twentieth century he would find that even greater things have been accomplished by the engineers now being trained in our technical schools, that the forces of nature have been more and more utilized until the energy of the beautiful cascades of the distant mountains has been carried into the homes of the people for their convenience and comfort, and, so long as civilization lasts, new and difficult problems will constantly arise to tax the skill of the engineer.

Civil Engineers' Society of St. Paul.

MARCH 4, 1895.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P. M. Present, 15 members and 5 visitors, President Stevens in the chair. Minutes of previous meeting read and approved. The following committee on standard wire gauges was appointed by the President: Mr. Crosby, Mr. Toltz, Mr. Merryman, Mr. Lyon and Mr. Hogeland. The question of the consolidation of the various U. S. surveys was referred to the Committee on Minnesota State Survey and Mr. Powell.

Mr. Truesdell read a paper entitled "The First Engineer." Hero, in his opinion, was the man to be honored with this title. Hero was the first to formulate and practically apply, 200 years B. C., the principles of geometry and mechanics. This pioneer instructor in practical science invented land surveying and leveling, and perfected innumerable engines of war and other constructions. An enthusiastic vote of thanks was accorded Mr. Truesdell.

Mr. Crosby displayed a number of drawings illustrating the solution of some of the problems met with during the construction of the 40-ton crane just completed by his company for the Mare Island Navy Yard.

C. L. ANNAN, Secretary.

Engineers' Club of St. Louis.

413TH MEETING, March 6, 1895.—Vice-President Ockerson called the club to order at 1600 Lucas Place, at 8.20 P. M.; twenty-three members and nineteen visitors present.

The minutes of the 412th meeting were read and approved, as corrected. The Executive Committee reported the doings of its 183d and 184th meetings, announcing the resignation of Mr. T. L. Condron.

The resignation of Mr. J. N. Judson, as librarian, was read, and, on motion, accepted. Ordered, on motion, that the matters of nominations for the office of librarian, and compensation for his services, be referred to the Library Committee, with request for a report at the next meeting.

The secretary read a letter from the chairman of the American Society of Mechanical Engineers' Committee on Standard Gauges for Thickness, requesting the appointment of a committee to co-operate with them in the matter. The secretary also read a report embodying the action of that committee, in conjunction with a committee of the American Railway Master Mechanics' Association. On motion it was ordered that a committee of three be appointed on this subject. The chair appointed Messrs. E. D. Meier, J. Kinealy and W. H. Bryan.

Prof. J. B. Johnson then addressed the club on the subject of "Wood Structure," explaining in detail the characteristics of the various woods commonly found in the markets, and the methods and appliances used in testing their strength. The lecture was illustrated by a large number of stereopticon views showing cross-sections which brought out plainly the characteristics of each wood. It was shown that the strength of the wood depends upon the proportion of solid to porous matter, the former being due to the rapid spring growth, and the latter to the slower summer and fall growth. He also showed that the strength was reduced as the percentage of moisture increased. He considered this the real explanation of Prof. Lanza's statement that large pieces of timber were weaker than small ones, as the laboratory tests had shown no difference in this respect. Messrs. Crosby, Kinealy, Moore, Wheeler and Winslow participated in the discussion.

Adjourned.

WILLIAM H. BRYAN, Secretary.

414TH MEETING, March 20, 1895.—President Russell called the club to order at 8.15 P. M. at 1600 Lucas Place. Twenty-five members and nine visitors present. The minutes of the 413th meeting were read and approved. The Executive Committee reported the doings of its 185th meeting. The following applications for membership were announced: George B. Leighton, vice-president Kansas and Texas Coal Co., and Joseph Ramsey, Jr., general manager Terminal Railroad Association.

Mr. J. A. Laird reported for the Committee on Library the nomination of Mr. W. A. Layman for librarian. He also reported progress in the matter of re-arranging the library. Mr. Laird's resignation as chairman had been accepted, and Mr. Julius Baier had been elected as his successor.

The secretary read the following report:

Mr. S. Bent Russell, C. E.

President The Engineers' Club, St. Louis, Mo.:

Dear Sir: Your Committee on Standard Gauges for Thickness of Metals beg leave to report as follows:

A letter from the American Society of Mechanical Engineers, dated February 21, 1895, to the Engineers' Club, asks us to co-operate with their society in the matter of recommending a gauge system based on actual thickness and diameters and state it in a decimal system. Your committee are unanimous in the opinion that the old arbitrary gauges now in use are apt to lead to confusion, and the course recommended by the joint committee of the American Society of Mechanical Engineers and the Railway Master Mechanics' Association is the right way out of the difficulty. It is absolutely necessary in mechanics and in business that standards should be plain, easily understood and of as wide acceptance as possible. Since it is not at present feasible to introduce the French system of measures used all over the Continent of Europe, in our practice, there can be no doubt that giving thicknesses in thousandths of the inch is the best practical method of designation.

Your committee therefore propose the following resolution:

Resolved, That the St. Louis Engineers' Club recommends to its members and urges upon all persons using a gauge system to abandon the use of arbitrary gauges and to give the actual thicknesses and diameters in thousandths of the inch.

Resolved. That the Secretary of the club be instructed to send copies of this resolution to the secretaries of the other associated societies, requesting them to concur, and to the secretary of the American Society of Mechanical Engineers.

In view of the fact that the American Society of Mechanical Engineers will send out copies of the proposed decimal gauge, this committee asks to be continued to enable them to take it up promptly when received.

Very respectfully submitted,

E. D. MEIER, Chairman.

J. H. KINEALY,

W. H. BRYAN, Committee.

On motion of Mr. Crosby, seconded by Mr. Perkins, the resolution proposed by the committee was adopted and the committee continued.

On motion the secretary was directed to cast the ballot of the club for Mr. W. A. Layman, as librarian, which was done.

Prof. W. S. Chaplin, chancellor Washington University, then addressed the club on the subject of German engineering schools and engineering education in general. He visited Germany in the summer of 1894 and took occasion to make a special study of the technical high schools in Berlin and Hanover. He was first struck with the size and magnificence of the buildings, the idea being that expenditures of this character would impress the people favorably, and tend to make the schools rank favorably in comparison with the older universities. The schools were provided with elaborate collections of models, representing all sorts of machinery. These models, however, were not used by the students, but by the professors only. Chemistry was taught to engineering students by lectures only. No students, except those intending to be chemists, were allowed to handle chemicals. The theses were accompanied by very fine drawings, but it seemed that all the designs and computations were made by the professors, the student simply executing the drawings under the immediate direction of the professors. It was nec-

essary to pass two important examinations, one at the end of two years and the other at the end of four years, at which time the student graduated, and took the State examination. It was necessary to pass the latter if the student expected to follow the profession and find employment.

The professors in the technical high schools were looked down upon by those in the universities. Engineers were considered technical and not scientific men. In a recent discussion among German engineers regarding engineering education, it was considered that a ground work in theory was absolutely essential, but it was necessary also that the student be taught the application of the theories to every day problems.

German engineering students put in from forty-one to forty-four hours per week at school, while thirty-five hours is considered large in this country. Besides this, it is necessary to do a considerable amount of home work at night.

The Professor had expected to learn many things of value, but was disappointed. He thought that, on the whole, the training given by American engineering schools was much better suited to American conditions. The technical high schools are entirely distinct from the universities. There are no graduate students. Instruction is simply by lectures, text books being used only in mathematics. The standard of entrance is higher than in our schools, and the course of study more thorough, but the field covered is not as wide or as general. The schools are supported almost wholly by government grants, the fees paid forming probably not to exceed 10 per cent. of the income.

The discussion was participated in by Messrs. Holman, P. N. Moore, Sterne, Johnson, Hermann, Laird, Kinealy, Crosby and Bryan.

Adjourned.

WILLIAM H. BRYAN, Secretary.

Montana Society of Civil Engineers.

HELENA, Mont., March 9, 1895.—The regular monthly meeting of the Montana Society of Civil Engineers was held on Saturday evening, March 9, at the society's rooms in the Denver block. The meeting was called to order by President Keerl, the following members being present: Messrs. James S. Keerl, William A. Haven, H. C. Relf, A. E. Cumming, A. S. Hovey and Forrest J. Smith. Several visiting engineers and F. H. Ray were also present.

The applications of William Monroe, David A. Herron and James M. Calderwood, for membership in the society were read and approved, and the secretary was directed to send out a letter ballot to the members to be canvassed at the next regular meeting. The secretary then read a memorial prepared by a committee of the society, of Col. Walter W. de Lacy, late president of the society, a pioneer, soldier and prominent civil engineer, who was known and loved from the Mississippi to the Pacific, and from the British possessions to the city of Mexico. The memorial entered into the details of the colonel's life, from the date of his birth in Virginia to the time of his death in Helena about three years ago. It was a most interesting paper, giving a short sketch of the many adventures of this most remarkable man among the savages of the unexplored west of early days, as well as his achievements in the engineering profession.

Mr. Ray, who has been most untiring in his efforts to secure the passage of the country surveyor and road law bills by the legislature, then reported

that while he was unable to secure the passage of those bills as originally drafted by the society, he did succeed in the passage of House Bill No. 356 and a substitute for House Bill No. 124; that hile these bills left much to be desired, they were a step in the direction of securing good roads without additional expense, and that by carrying on a "campaign of education" we would in a few years be able to obtain the proper legislation to put the location and construction of our highways in the hands of men trained to the work.

A vote of thanks was given Mr. Ray for his work done in the interest of "good roads," and he was invited to attend the meetings of the society. The secretary was also directed to communicate with Senators Folsom, Steele and Babcock; Representatives Shropshire, Tallant, Isdell, Metcalf, Gordon and Craven, and Messrs. Beach, Muth and Wheaton, commissioners of Lewis and Clarke county, and express the thanks of the society to them for the interest they took in the reform of our county surveyor and road laws, and for the aid they gave to the movement.

J. H. Farmer was present, with a paper on "Steam Power in Relation to Our Mills and Manufactures, Compared with Water Power by Electrical Transmission," but, as it was quite late, it was decided to defer the reading of this paper until the next meeting, when it is hoped that there will be a larger attendance, as the paper deals largely with the proposed Missouri River dam near Stubbs ferry and the transmission by electricity of power to this city.

A letter was read from Surveyor General Straughan, of Idaho, quoting the recent rulings of the Secretary of the Interior, in which he holds that a deputy United States mineral surveyor, residing in one State, may hold a deputy's commission and make mineral surveys in another State, thus reversing the ruling of the commissioner of the general land office.

The meeting then adjourned.

F. J. SMITH, Secretary.



Bradley & Poates, Engr's, N. Y.

ASSOCIATION OF ENGINEERING SOCIETIES.

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PROCEEDINGS.

Montana Society of Civil Engineers.

HELENA, Mont., April 13, 1895.—The regular monthly meeting of the Montana Society of Civil Engineers was held on Saturday evening, April 13, at the society's rooms, in the Denver Block. The meeting was called to order by President Keerl, the following members being present: Messrs. James S. Keerl, William A. Haven, H. C. Relf, Harry V. Wheeler and Forrest J. Smith. Mr. H. L. Cooper, of Minneapolis, member of the Western Society of Civil Engineers, and Mr. J. H. Farmer were also present.

Messrs. Haven and Wheeler were appointed tellers to canvass the ballots for admission to membership, and upon the completion of the count the president announced that Charles A. Molson, James M. Calderwood, David A. Herron and William Munroe had been elected members of the society.

A letter bearing date of March 14, from Walter H. Weed, of the Geological Survey at Washington, D. C., asking the society's opinion as to the most important area in Montana in which to prosecute this season's work was then read. The secretary stated that owing to the fact that immediate action had been necessary, and as the matter was of prime importance to the mining engineers of the State, he had referred the matter to the members of the society residing in Butte. They had met and discussed the subject and were of the opinion that the area demanding immediate attention is the degree square included between the 113th and 114th meridians, and the 46th and 47th parallels of latitude, which covers the mines of Granite, Philipsburg, Georgetown, Cable, Combination, Sunrise, Yreka, Royal Beartown, etc. The secretary also said that the Helena engineers were of the opinion that the most important area is that section which covers the mines of Basin, Lump Gulch, Red Mountain, Marysville, Jay Gould, Elkhorn, Radersburg, St. Louis, etc., and that he had written Mr. Weed, laying before him the two different opinions of the members, and that no doubt one of the two sections would be selected in which to carry on the government geological work this season.

Letters were read from Senator Babcock and Representatives Shropshire and Craven, expressing their appreciation of the society's efforts to

obtain legislation favorable to the improvement of our public highways, and also expressing the belief that in the near future legislators would realize the great importance of this subject and grant proper legislation.

Mr. J. H. Farmer then read a paper on "Steam Power in Relation to Our Mills and Manufactures, Compared with Water Power by Electrical Transmission." The paper was most interesting and gave evidence of thorough research and careful study on the part of the author, who is undoubtedly thoroughly familiar with the subject. It entered into the details of construction and cost of building a dam across the Missouri River, near Stubbs' Ferry, and transmitting the power by electricity to this city. It also developed the facts that the cheapest results obtained by recent tests, made by two of the largest plants in the State, of the cost per horse power per year generated by steam, was \$71.50; while Mr. Farmer estimates that power can be transmitted from the dam to this city at \$16.78 per horse power per year. A careful estimate shows that Helena now uses about 2000 horse power, and, in view of the fact that this would be more than doubled in a short time by the use of the cheap power mentioned above, it seems strange that capitalists should hesitate with a project which promises such large returns. A vote of thanks was given Mr. Farmer for his valuable paper, and the meeting adjourned.

FORREST J. SMITH, Secretary.

Civil Engineers' Society of St. Paul.

ST. PAUL, April 1, 1895.

A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P. M., thirteen members and twelve visitors were present. In the absence of the presiding officer Mr. A. O. Powell was called to the chair. Following the reading of the minutes of the previous meeting, Mr. C. A. Winslow was elected a member of the society.

Mr. George L. Wilson then read a brief historical sketch of the Chicago Drainage Canal, and illustrated, by lantern views, the method of excavating on several sections of the work. The pictorial display elicited many questions, which were satisfactorily met, and Mr. Wilson was quite generally given to understand that his work was thoroughly appreciated. Vice-President Hilgard appeared in time to close the meeting.

C. L. ANNAN, Secretary.

Engineers' Club of St. Louis.

415th Meeting.

April 3, 1895.

The club was called to order at 1600 Lucas Place, at 8.30 P. M., President Russell in the chair; fifteen members and six visitors present.

The minutes of the 414th meeting were read and approved. The Executive Committee reported the doings of its 186th meeting, approving the applications for membership of Joseph Ramsey, Jr. and George B. Leighton. They were balloted for and elected. An application for membership was announced from Thomas Ashburner, St. Louis agent of the Babcock & Wilcox Company.

Professor J. H. Kinealy then addressed the club on the "Different Methods of Determining the Heat Value of Fuels." Three plans are in common use: The Analytical, Bertier and Calorimetric. In the first

method the calorific power is computed from the chemical constituents of the fuel, they having first been determined by analysis. This process was open to the criticism that the heat value of pure carbon had been shown to vary as much as 3 per cent., depending upon the condition of the carbon. This computation also neglected the sulphur. On the whole, however, he considered this plan the best of the three.

In the second or Bertier method, the coal was burned in the presence of litharge, the heat value being assumed to be proportioned to the amount of oxygen absorbed from the litharge. This principle has been shown, however, to be erroneous, but the method nevertheless gives good comparative results.

The apparatus used in the third method is usually the Thompson calorimeter, in which the coal is burned in such a way as to give up its heat to a surrounding body of water of known weight, the rise in temperature of which is noted. This method was shown to have a considerable error depending upon the temperature of the water used and the heat absorbed by the apparatus itself. Its accuracy depends upon very close reading of thermometers. This method assumed that complete combustion of the coal occurred, which the speaker doubted. This possibility he proposed to investigate further by analyzing the discharge gases.

Messrs. Johnson, Fish, Moore and Bryan took part in the discussion.

Adjourned.

WILLIAM H. BRYAN, Secretary.

416th Meeting.

April 17, 1895.

The Club was called to order at 8.15 P. M., by President Russell, at 1600 Lucas Place. Eighteen members and six visitors present.

The minutes of the 415th meeting were read and approved. The Executive Committee reported the doings of its 187th meeting, approving the application for membership of Mr. Thomas Ashburner. He was balloted for and elected. An application for membership was announced from Mr. H. A. Wagner, general superintendent of the Missouri Electric Light and Power Company and Edison Illuminating Company.

The secretary announced the receipt of a number of valuable publications for the library.

Professor Johnson then introduced Professor Leonard S. Smith, of the University of Wisconsin, Madison, Wis., who read a paper on "An Experimental Study of Field Methods which will Insure Greatly Increased Accuracy to Stadia Measurements."

The Professor had had occasion to make an exhaustive study of stadia methods and the effect of work done at various hours of the day, and under varying conditions of the atmosphere. Two points were covered: First, a study of what is known as boiling or unsteadiness of the air, the effect of which he termed differential refraction; second, the effect of this refraction upon the accuracy of stadia measurements.

The Professor had spent considerable time on this work in connection with the international boundary survey between this country and Mexico, and his experiments were continued last summer at Madison, Wis. His researches, which were very exhaustive, and made with the greatest care, enabled him to formulate some general suggestions regarding stadia work, which, if followed, would enable that system to be employed satisfactorily on work requiring a greater degree of accuracy than has heretofore been deemed possible.

In the discussion which followed, participated in by Messrs. Holman,

Kinealy, Johnson, Ockerson, Colby and Van Ornum, the universal opinion was that Professor Smith's work was of great value to the profession, as it marked a decided advancement in our knowledge of stadia work.

On motion it was ordered that the Club extend a vote of thanks to Professor Smith for his paper.

Adjourned.

WILLIAM H. BRYAN, Secretary.

Civil Engineers' Club of Cleveland.

CLEVELAND, O., April 9, 1895.

The meeting was called to order by President Mordecai at 7.45 o'clock. There were present thirty-seven members and visitors. Minutes of the last meeting, on March 12, were read and approved.

The application of Mr. Stephen Balkwill for admission to the Club as associate member was announced as approved by the Executive Board, and the following committees as appointed by the President:

Program Committee, Prof. C. H. Benjamin, chairman; Messrs. John Richardson, E. S. W. Moore, H. Grey, W. Rice, C. S. Howe and E. A. Handy. Finance Committee, Messrs. C. W. Wason, J. C. Wallace and W. Miller. Library Committee, Messrs. James Ritchie, J. L. Culley and F. A. Coburn.

A letter was read from the Electric Club extending thanks for the souvenir engraving. Letters were read from Professor J. B. Johnson, chairman of the Board of Managers of the Association of Engineering Societies, and Mr. John C. Trautwine, Jr., secretary, expressing their appreciation of our vote of thanks, and also from the secretary, making suggestions regarding advertisements in the journal.

Professor Benjamin, chairman of the Program Committee, reported progress in arranging the program for the coming year.

It was moved by Mr. William H. Searles and carried, that a committee of three on advertising be appointed by the President.

It was moved by Mr. Walter Miller and carried, that a committee of three upon new quarters be appointed by the President.

Professor Charles S. Howe then presented his paper: "Solar Attachments to Transits," and, in the absence of Mr. John B. Davis, Professor Howe continued, describing that gentleman's invention of a "New Solar Instrument."

Discussion of the subject was engaged in by Messrs. W. T. Blunt, William H. Searles, C. G. Force, J. D. Varney and B. F. Morse.

The President announced, as Committee on Advertising, Messrs. W. H. Searles, James Ritchie and C. M. Barber. As Committee on New Quarters, Messrs. W. Miller, A. H. Porter and J. C. Beardsley.

The meeting adjourned at 9.15 o'clock.

F. A. COBURN, Secretary.

Technical Society of the Pacific Coast.

April 5, 1895. Regular meeting. Called to order at 8.30 P. M. by President Dickie.

The minutes of the last regular meeting were read and approved.

The following candidates were declared duly elected to membership in the society after a count of the ballots:

MEMBERS.

Marion L. Cook, of Riverside, Cal.

Ernest F. Rossow, of Vallejo, Cal.

Albert I. Frye, of San Francisco, Cal.

The following names were proposed and referred to the Executive Committee:

FOR MEMBERS.

Walter E. Downs, Civil Engineer, of Sutter Creek, Cal. Proposed by Frank Soule, H. E. Clermont Feusier and Otto von Geldern.

Jno. B. Leonard, Draughtsman, of San Francisco. Proposed by J. H. Wallace, G. W. Dickie and John D. Isaacs.

Franklin Riffle, Civil Engineer, of San Francisco. Proposed by D. C. Henny, Thos. W. Brooks and H. C. Behr.

Mr. John D. Isaacs, of the Southern Pacific Company, read a paper entitled "Stopping a Troublesome Slide at a Summit Tunnel," which gave rise to an interesting discussion in which many of the members participated.

Adjourned.

OTTO VON GELDERN, Secretary.

The Secretary announces the death, on April 21, 1895, of Mr. George Beardsley, of Phoenix, Arizona, member of the Society.

Association of Engineers of Virginia, Roanoke, Va.

March 28, 1895.—The regular informal monthly meeting of the Association was held on March 28th, being postponed from March 20, on account of the very inclement weather. The meeting was called to order by the president, Mr. J. C. Rawn. An invitation to the Association from the Engineers' Club of the Va. A. and M. College to attend the lectures of Professor J. H. Gore, of Columbian University, on Geodecy, to be delivered April 5th and 6th, was read, and the secretary instructed to express the thanks of the Association. A communication from the librarian of the Ohio State University was read, asking for the publications of the Association of Engineers of Virginia. The secretary was instructed to send what had already been published and to state that hereafter all the papers of the Association would be published in the "Journal of the Association of Engineering Societies."

A communication from the Engineers' Club of St. Louis was read asking that this Association use its influence in bringing into general use the "Decimal Gauge" for wire and sheet metal that is to be proposed by the American Society of Mechanical Engineers and the American Railway Master Mechanics' Association.

A committee, consisting of Messrs. G. R. Henderson, C. S. Churchill and R. H. Soule, was appointed to draw up resolutions expressing the views of the Association in this matter and report.

The paper for the evening, "Cement from Furnace Slag," was called, and a very complete and interesting discussion of the subject was given by Mr. Herman Crueger. The chemical analysis of the various kinds of cement was given and along with it the analysis of the various furnace slags to be had in this section, showing clearly that it would be an easy matter to produce good cement at very low cost. The plan for a factory for its production, with estimates of cost, etc., were also given, making it a very interesting and instructive meeting. Paper referred to Publication Committee. Meeting adjourned.

JNO. A. PILCHER, Secretary.

April 17, 1895.—The regular informal monthly meeting of the Association was called to order, with President J. C. Rawns in the chair and a good number of the members present.

Professor L. S. Randolph, of Blacksburg, Va., read a very interesting paper on "Engineering Education," in which he brought out the distinctive features in the methods of teaching in England, in Germany and in America. The weak and the strong points of the different systems were brought out and discussed and the very important question of just how far the student in one branch of the profession should be carried into the others was raised. Also the question of how much time should be given to the practical and how much to the theoretical part of the training.

The discussion was entered into by a good number of those present and views on the subject were expressed by those who had seen or been under the different plans of instruction. The varied opinions and experiences of those who had seen the service were interesting and instructive.

The paper was referred to the Publication Committee.

Very truly,

Roanoke, Va.

JNO. A. PILCHER, Secretary.

Boston Society of Civil Engineers.

APRIL 17, 1895—A regular meeting of the Society was held at its rooms, 36 Bromfield street, Boston, at 7.50 o'clock P. M. Sixty-five members and visitors were present.

President Albert F. Noyes, on assuming the chair, thanked the members for the honor conferred upon him in his election to the presidency for the coming year. He promised the society his best efforts to advance its work and solicited the earnest co-operation of each and every member.

The Secretary reported for the Board of Government that it had appointed the following special committees:

On Excursions—H. B. Wood, H. S. French, W. B. Fuller, J. W. Rollins, Jr., and I. N. Hollis.

On the Library—F. L. Locke, S. E. Tinkham, H. D. Woods, F. E. Sherry and M. S. Pope.

On Quarters—Thomas Doane, Desmond FitzGerald, E. W. Howe, M. M. Tidd and C. F. Allen.

Members of the Board of Managers—S. E. Tinkham, J. R. Freeman, Henry Manley and Fred. Brooks.

The report was accepted.

The Committee on Weights and Measures, which had been given until this meeting in which to submit its annual report, not having presented a report, on motion it was voted to refer to the Board of Government, with full powers, the continuance of the committee and the appointment of the members thereof.

The Secretary read a communication from the Board of Directors of the American Society of Civil Engineers, inviting this society to attend the annual convention to be held at the Hotel Pemberton, beginning June 18, 1895, and suggesting that it would be pleased to have the Boston Society co-operate in any way with the local committee of arrangements. The invitation was accepted, with the thanks of the Society, by a unanimous vote.

It was further voted, that a committee of three, to represent the Boston Society of Civil Engineers, be appointed by the President to aid the local committee of the American Society Civil Engineers in its work. Later in the meeting, the President named as the members of the committee, Messrs. Dexter Brackett, Fred. Brooks and T. Howard Barnes.

A communication was read from the Engineers' Club, of St. Louis, calling attention to the action of that club on the question of standard gauges for thickness of metals, and requesting this society to concur in the proposed action. It was voted to refer the communication to the Board of Government, to be reported upon in connection with the communication on the same subject from the American Society of Mechanical Engineers, now before the Board.

On motion of Mr. Wood, the thanks of the Society were voted to Major J. W. Reilly, U. S. A., for courtesies shown our members on the occasion of the visit to the Watertown Arsenal this afternoon.

The president announced the deaths of two members of the Society, John H. Webster, who died on April 2, 1895, and Adelbert L. Sprague, who died April 12, 1895. On motion the President was requested to appoint committees to prepare memoirs, and the following appointments were made: On memoir of Mr. Webster, Messrs. J. A. Tilden and J. R. Freeman; on memoir of Mr. Sprague, Messrs. F. O. Whitney and F. A. Foster.

Mr. Walton I. Aims, C. E., of New York, was then introduced, and read a paper entitled "Notes on the Construction of the East River Gas Tunnel."

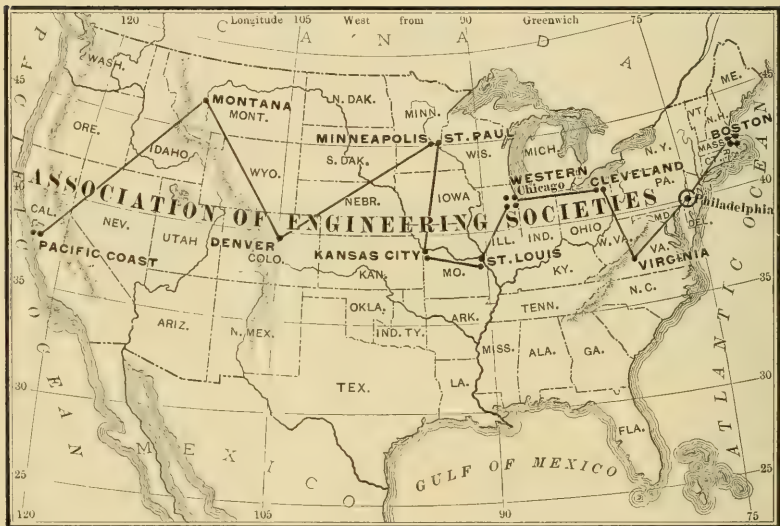
The paper gave a very full history of the work, and was illustrated by a large number of lantern views showing the details of the work.

At the close of the discussion which followed the reading of the paper, on motion of Mr. FitzGerald, the thanks of the Society were extended to Mr. Aims for his very interesting and valuable paper.

On motion of Mr. Stearns it was voted to hold the June meeting of the Society on the 12th of that month.

Adjourned.

S. E. TINKHAM,
Secretary.



Bradley & Pontes, Eng'rs, N.Y.

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XIV.

MAY, 1895.

No. 5.

PROCEEDINGS.

Engineers' Club of Minneapolis.

NOVEMBER 19, 1894.—Regular meeting called to order at 8 P.M., by the President, F. W. Cappelen, who announced the death of Charles F. Chapman, one of the early members of the Club.

William A. Pike stated that, as Secretary at the time, he could vouch for his having been an active member during his active connection with the Club, and moved that a committee be appointed by the Chair to draw up suitable resolutions. Carried. The Chair appointed as such committee, W. A. Pike, F. C. Deterly, I. E. Howe, and M. W. Hoffman.

Letter was read from O. Chanute, C.E., transmitting souvenir and medal from French Society, as a recognition of the treatment their delegates to the World's Columbian Exposition had received.

W. A. Pike reported as member of Board of Managers of JOURNAL of Associated Engineering Societies, that there was a deficit, and several plans for overcoming the same, and asked instructions.

W. A. Hoag moved to leave the matter in W. A. Pike's hands, and that the Club will sustain his action, also that the opinion of the Club was that the best plan was to make the necessary assessment to cover deficit. Carried.

The Committee then reported the following:

Whereas it has come to the knowledge of this meeting that Charles F. Chapman has been called away. Therefore we

Resolve, That in his death we have lost a most able and trustworthy engineer and friend, and we, as engineers, desire to express to his family our sincere regret for his loss, and our deepest sympathy with them.

On motion the report and resolutions were unanimously adopted, and the Secretary instructed to transmit a copy to the family.

On motion of I. E. Howe, F. C. Deterly, I. E. Howe and M. W. Hoffman were appointed a committee to represent this meeting at the funeral, and were empowered to procure flowers.

W. R. Hoag then read a paper on the State Topographical Survey of Minnesota.

E. E. Woodman, H. C. Stevens, and K. E. Hilgard, of the St. Paul Society, were present.

Moved that a committee be appointed to investigate the continuation of the State Topographical Survey, consisting of F. W. Cappelen, as Chairman, E. T. Abbott, and W. A. Pike. Carried.

E. E. Woodman, of the St. Paul Society, stated that their Society would at their next meeting appoint a committee to act with our committee.

On motion adjourned.

ELBERT NEXSEN, *Secretary*.

DECEMBER 17, 1894.—Regular meeting held at the Public Library, at 8 P.M., President F. W. Cappelen in the chair. Minutes of Meetings of March 19th, April 16th, May 21st, June 18th, July 16th, August 20th, September 7th, and November 19th, and also record of trip of Club and St. Paul Engineering Society, October 20th to 23d to Sault Ste. Marie, were read and approved.

Secretary read letter from Mrs. Charles F. Chapman thanking the Club for the resolution and flowers sent at the time of her husband's death.

F. W. Cappelen, Wm. A. Pike and E. T. Abbott, the committee appointed at the last meeting to consider the subject of the Topographical Survey of Minnesota, reported.

I. E. Howe moved the report be adopted. Carried.

Moved that a copy of the report, and the fact of its adoption by the Club, be sent by the Secretary to Hon. John S. Pillsbury, President of the Board of Regents of the University of Minnesota, to our United States Senators, W. D. Washburn, and C. K. Davis, and to our United States Representatives in Congress, J. A. Towney, J. T. McCleary, O. M. Hall, A. R. Kiefer, Losen Fletcher, M. R. Baldwin, H. E. Boen, and the Press of Minneapolis, and that the Secretary notify E. E. Woodman, of the Civil Engineers' Society of St. Paul, of the action taken. Carried.

On motion adjourned.

ELBERT NEXSEN, *Secretary*.

JANUARY 21, 1895.—The annual meeting was adjourned to February 4, 1895, as the Secretary and Treasurer had been suddenly called away from the city.

FEBRUARY 4, 1895.—Adjourned annual meeting held at the Public Library, at 8 o'clock, the President, F. W. Cappelen, in the chair.

The report of the Treasurer, showing receipts of \$115.00 during the past year, and expenditures of \$119.27, and a balance of \$30.27 on hand to meet liabilities of \$90.50, with assets due from members of Club, mostly good but slow, of \$75.50, and recommending that the assessment for 1895 be made \$5.00 for each member, payable at once, was read, and Carl Ilstrup appointed auditor to audit the accounts.

The Secretary's report was a statement of what the Club had done and is fully shown in the minutes.

These reports were accepted and ordered placed on file.

A motion making the assessment for current expenses for 1895, five dollars (\$5) per member, payable at once, was carried unanimously.

The election of officers was postponed to a future meeting.

Mr. Harry W. Jones then read a paper embodying his views upon what an architect should be, and this was discussed by Mr. W. A. Pike, F. W. Cappelen, and A. B. Coe.

W. A. Pike offered the Club the use of his office, rent free, No. 822 Guaranty

Loan Building, as a place of meeting, and on motion the offer was accepted with the thanks of the Club.

The thanks of the Club were extended to Mr. Harry W. Jones for his very interesting paper, and a copy of the same requested.

On motion adjourned.

ELBERT NEXSEN, *Secretary*.

MARCH 18, 1895.—A regular meeting was held at 822 Guaranty Loan Building at 8 o'clock P.M., and Wm. A. Pike was chosen chairman.

Minutes of previous meetings read and approved.

Communications as follows were read: Invitations from Civil Engineers' Club of Cleveland to F. W. Cappelen, as President, to be their guest at their Fifteenth Annual Banquet on March 20th; from the Boston Society of Civil Engineers extending a like invitation to their Thirteenth Annual Dinner on March 12th to our Secretary.

From the Secretary of the Civil Engineers' Society of St. Paul, transmitting a copy of resolutions, correcting a statement made in a Preamble to resolutions adopted by them February, 1895, on the subject of the United States Surveys, and as explanatory of this communication, the correspondence between the Presidents of the St. Paul Society and our Club.

On motion of Mr. Howe the Secretary was directed to express to the St. Paul Society the fact that the resolutions as transmitted were satisfactory as placing the facts relative to the drafting and adoption of the resolutions mentioned, relative to the United States Surveys, as jointly agreed upon by the committees of each Society.

The final report of the Committee on Efflorescence of Brick was then read by the Secretary, and discussed by Carl Ilstrup, I. E. Howe, and the Chair, all taking exception to some of the conclusions reached by the Committee, because the specimens as mounted were placed flat when exposed, with backing brick below and face brick above, instead of vertically, as the brick would be built in a wall—all considering this arrangement faulty. On motion the report was accepted, and ordered placed on file, and the committee discharged.

W. S. Pardee's bill for a balance of \$11.80 for labor, material, etc., incurred by the Committee on Efflorescence of Brick, was presented and on motion of W. W. Redfield, the Secretary was directed to credit the same on account of W. S. Pardee's dues to the Club.

The chairman then announced the next business as the election of officers for 1895.

I. E. Howe moved that the election be postponed after a general discussion in which the unanimous sentiment was that it had been postponed too long already. The motion was lost.

E. H. Loe moved that the Secretary be instructed to cast the ballot of the Club for F. W. Cappelen for President. Carried unanimously.

The same motion by Carl Ilstrup, carried unanimously for I. E. Howe for Vice-President. These ballots having been cast by the Secretary and announced by the Chair, a motion that the Vice-President-elect cast the ballot of the Club for Elbert Nexsen for Secretary and Treasurer, and A. B. Coe for Librarian, and Wm. A. Pike for Member of the Board of Managers of the Association of Engineering Societies, was unanimously adopted, and so cast by him, and they were declared duly elected by the Chair to the several offices.

The name of Pedar Erlandsen was proposed for membership by Carl Ilstrup, and I. E. Howe.

On motion adjourned.

ELBERT NEXSEN, *Secretary*.

Engineers' Club of St. Louis.

417TH MEETING, MAY 1, 1895.—President Russell called the Club to order at 1600 Lucas Place, at 8.25 P.M. Eighteen members and three visitors present. The minutes of the 416th meeting were read and approved. The Executive Committee reported the doings of its 188th meeting, announcing the approval of the application for membership of Mr. H. A. Wagner, general superintendent of the Missouri Electric Light and Power Company and Edison Illuminating Company. He was balloted for and elected. An application for membership was announced from Mr. Fred Schwedtmann.

The Secretary read a circular letter from the Western Society of Engineers on the subject of keeping the cost of the JOURNAL down to \$3 00 per annum per member. After discussion by Messrs. Moore, Crosby, Kinealy, Winslow, Wheeler, Ockerson, Thacher and Bryan, Mr. Moore offered a resolution to the effect that it was the sense of this Club that the cost of the JOURNAL be limited to \$3.00 per year per member, and that, if necessary to keep the cost within this limit, the "Proceedings" be omitted. This motion was seconded by Mr. Crosby and adopted.

Mr. William H. Bryan then addressed the Club informally on the subject of "Boiler Trials," the objects of which were usually the determining of the efficiency, capacity or smokelessness of the plant. He explained how such trials were made, the apparatus and instruments employed, and the results obtained, paying particular attention to the question of entrainment, or moisture present in the steam. He showed the Barrus and Carpenter Calorimeters for determining the quality of the steam, and explained their construction and use.

He gave the following figures as the result of a large number of investigations made on boilers and furnaces in and near St. Louis, burning soft coals:

Average efficiency of the common boiler and furnace, 51.35 per cent.; range, 44.8 to 60.4 per cent. Water tube boilers with common furnace, 60 to 70 per cent. Best form of improved furnace, under ordinary boilers, 58 to 69 per cent.; under water tube boilers, 70 to 75 per cent.

In capacity, the maximum evaporation in pounds water per square foot surface per hour from and at 212 degrees, was as follows:

For boilers with 2½-inch tubes	4.17
For boilers with 6-inch tubes	7.81
Flue boilers	8.86
Water tube boilers	7.26

The capacity on the basis of percentage of work done above the normal capacities of the boilers was as follows:

Boilers with 2½-inch tubes	81 per cent.
Boilers with 6-inch tubes	113 per cent.
Boilers with large flues	92 per cent.
Boilers with water tubes	70 per cent.

In smoke performance the average of five tests, made on common boilers and furnaces, was 44.7 per cent.—the range being from 11 per cent. to 75 per cent. The average of 18 determinations on improved furnaces was 7.8—the range being from .300 to 40 per cent. Deducting the latter abnormal figure, which was clearly due to inefficient handling, the average of the remaining 17 was 5.91.

Mr. Bryan then gave the results of some trials recently made on the boilers of the St. Louis & Suburban Railway. The boilers were of the ordinary horizontal type, with 6-inch flues. The first trial was made on boilers set with the Hawley furnace, the result in efficiency being 57.75 per cent., and the cost of evaporating 1,000 pounds of water, 12.2 cents, with Mount Olive lump coal, costing \$1.50 per ton of 2,000 pounds.

The second test was made on similar boilers with the ordinary furnace, the result being 48.83 per cent., and 14.1 cents, respectively.

The third test was made on the same boilers burning slack coal costing \$1.10, with results of 47.98 per cent., and 11.5 cents.

The fourth run was made with lump coal, with an automatic steam jet smoke abater attached, the result being 50.70 per cent. and 13.8 cents. Same results, corrected for steam used for jets, were 49.16 per cent. and 14.3 cents.

The steam used for the jets was supplied by an independent 8-horse power boiler, which was tested at the same time, giving results of 34.62 per cent. and 21.3 cents.

These figures indicate that no economy in fuel resulted from the use of the apparatus, but, on the other hand, it occasioned no loss. Some careful tests made by others indicate a fuel economy of from 5 to 10 per cent. under the best conditions, but Mr. Bryan was of the opinion that the ordinary non-automatic steam jets have usually increased the fuel bills.

Discussion followed by Messrs. Kinealy, Ockerson, Winslow, Laird and Wheeler.

Adjourned.

WILLIAM H. BRYAN, *Secretary*.

418TH MEETING, MAY 15, 1895.—President Russell called the Club to order at 1600 Lucas Place at 8.20 P.M. Twenty members and ten visitors present.

The minutes of the 417th meeting were read and approved. The Executive Committee reported the doings of its 189th and 190th meetings.

The Secretary read an informal progress report of the Committee on Standard Gauges for Thickness, showing that the movement for a decimal system was receiving widespread consideration and approval. The Secretary also read a letter from the Chairman of the Board of Managers of the Associated Engineering Societies, stating that immediate steps would be taken to make such changes as were necessary to keep the cost of the JOURNAL within \$3.00 per member per year.

Mr. M. A. Howe, Professor of Civil Engineering, Rose Polytechnic Institute, Terre Haute, Ind., then addressed the Club on the subject of "Recording Bridge Deflections." He described in detail a series of experiments made by himself and classes of students in 1892 and 1894, the primary object being the collection of data for the students' theses. Very complete measuring and recording apparatus had been devised to determine the effect of moving and stationary loads on pin connected bridges, in vertical, lateral and longitudinal deflections, these three being recorded independently.

The Professor was of the opinion that the vibrations were much less than had been heretofore assumed. In several cases he had computed the deflections from approved formulæ and had found the result considerably more than that actually observed. In the particular cases considered, he believed this due to the fact that the top and bottom chords were practically continuous girders, and therefore carried a large proportion of the strain.

The discussion was participated in by Messrs. Crosby, Johnson, Ockerson, Moore, Baier and Sterne.

It was stated that the counterbalancing of locomotive drivers had been very much overdone, and that the best practice nowadays was to reduce it materially.

On motion of Professor Johnson, a vote of thanks was tendered Professor Howe for presenting his paper in person.

Adjourned.

WILLIAM H. BRYAN, *Secretary*.

Technical Society of the Pacific Coast.

REGULAR MEETING HELD MAY 3, 1895. Called to order by President Dickie. The minutes of the last regular meeting were read and approved. After regular ballot the following gentlemen were declared duly elected members of the Society: Walter E. Downs, Civil Engineer; John B. Leonard, Civil Engineer; Franklin Riffe, Civil Engineer.

Mr. John B. Leonard thereupon read a paper entitled "Reconstruction of the Ferry Transfer Aprons at Port Costa and Benicia," after which a full discussion of the subject was entered upon. Adjourned.

OTTO VON GELDERN, *Secretary*.

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., MAY 6, 1895.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.15 P.M. Fifteen members and five visitors were in attendance, President Stevens presiding. Minutes of previous meeting were read and approved. A circular letter from the Board of Directors of the Western Society of Engineers, relating to the prospective cost of publication of the JOURNAL of the Association was referred to Representative Woodman with power to act. As a matter of suggestion votes were taken to determine the sense of the meeting on two points only, with the following result: (1) Should it become necessary to discontinue any one department of the JOURNAL, the "Proceedings" should be dropped. (2) The "Index to Current Literature" should remain a feature of the JOURNAL at all events.

The following report of the Committee on Standard Wire Gauges was read and accepted. Mr. J. D. Estabrook then read a description of the new steam plant at the Washburn Flour Mills in Minneapolis, and Mr. William A. Pike described a test of its main feature, the Schichau Engine.

The discussion was somewhat extended over foaming glass and sandwich at the Café Neuman.

C. L. ANNAN, *Secretary*.

ST. PAUL, MINN., May 6, 1895.

President of the Civil Engineers' Society, St. Paul, Minn.:

DEAR SIR.—The committee appointed to investigate standard gauges by request of the American Society of Mechanical Engineers begs leave to make the following report:

Your committee are unanimously of the opinion that the gauges now in use, of which there are about forty (40), are in a state of confusion, and one of the most

serious matters in connection with the present system is the uncertainty of ordering material to a standard gauge, and also the gauge number as now used conveys no idea as to the thickness of the plate or wire designated. We would, therefore, recommend the use of a standard gauge, using as a basis the one-thousandth of an inch.

We do not believe that the French system of measurement has made any material progress among the manufacturers and mechanics of the United States, and therefore do not believe it would be advisable to undertake to measure with the French system as a gauge basis.

Your committee, therefore, proposes the following resolutions :

Resolved, That the Civil Engineers' Society of St. Paul recommends to its members, and to manufacturers using a gauge system, to abandon the old arbitrary gauges now in use and give the actual thickness and diameters in thousandths of the inch.

Resolved, That the Secretary of the Club be instructed to send copy of this report to the Secretary of the American Society of Mechanical Engineers, indorsing their report in reference to gauges.

Respectfully,

OLIVER CROSBY, *Chairman*.

TRACY LYON.

A. H. HOGELAND.

MAX TOLTZ.

W. C. MERRYMAN.

At a special meeting of the Civil Engineers' Society of St. Paul, held May 30, 1895, the following resolution was passed :

Whereas, the Civil Engineers' Society of St. Paul, after examining the maps and works of the United States Geological Survey, and approving of the methods and work heretofore done in this vicinity, is desirous that the same should be continued. Therefore,

Resolved, That assaid work is of great economic value to the Twin Cities, we do hereby request Senator Davis to urge the continuation of the work in the territory contiguous to the Twin Cities and the publication of maps of the same.

C. L. ANNAN, *Secretary*.

Montana Society of Civil Engineers.

MAY 13, 1895.—The regular monthly meeting of the Montana Society of Civil Engineers was held at the Secretary's rooms in the Denver block on Broadway. President Keerl called the meeting to order, the following members being present : Messrs. Keerl, Haven, Bayliss, Henley, Kelley and Smith. The application of Frederick J. Taylor for membership to the society was read and approved and the Secretary was instructed to prepare a letter ballot and send it to the members, to be canvassed at the next regular meeting.

A committee consisting of A. E. Cumming and H. V. Wheeler was appointed to prepare new forms of "quartz locations" and "water rights" to conform to the new law passed by the last legislature. This committee will report at the meeting to be held June 8, and as the new law does not go into effect until July 1, it is the

hope of the society that the printers generally will adopt these new forms and thus secure uniformity throughout the State.

The Secretary read a letter from the Board of Directors of the Western Society of Engineers, of Chicago, in reference to the cost of publishing the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. A committee consisting of W. A. Haven and C. W. Goodale was appointed to investigate the matter thoroughly and report at the next regular meeting.

FORREST J. SMITH, *Secretary*.

The Civil Engineers' Club of Cleveland.

MAY 14, 1895.—Notwithstanding a severe storm, members of the Club and visitors to the number of twenty met at Case Library in the afternoon, visited Case School of Applied Science and united with others in an inspection of that enterprising, modern college.

The complete facilities for study and investigation there shown and the thorough methods of teaching, were examined and appreciated.

The party, numbering thirty, took supper at the Forest City House, after which they adjourned to the rooms of the Club at Case Library.

The meeting was called to order at 7.45 p.m. by President Mordecai. There were present 93 members and visitors. The Club dispensed with the reading of the minutes. Messrs. Herman, Thompson and Constant were appointed tellers to canvass ballots.

Reports were given by the Executive Committee and the Committee on Advertising and the complete program for the meetings for the year, as prepared by the Program Committee, was read; after which the Club listened to the paper of the evening by Dr. Dayton C. Miller.

The object of the lecture was to explain polarized light in a simple and concise manner. The elementary phenomena of light were briefly treated. Polarized light, its production and detection, were described. The beautiful color phenomena, resulting from the action of thin plates of doubly refracting substances upon the polarized light, showing designs in complementary colors, and the ring system of crystals, were explained and exhibited. Brief mention was made of the application of polarized light in the arts. The lecture was beautifully illustrated by means of an arc light projection polariscope.

This interesting lecture and beautiful exhibition were enthusiastically received by the unusually large audience.

The tellers reported the election of Mr. Stephen Balkwill to associate membership, and at 10 p.m. the meeting adjourned.

A pleasant innovation at this evening's meeting was the presence of ladies, some of whom had attended the excursion of the afternoon and the supper afterward.

The gentlemen enjoyed their presence. May they be with us often.

FOREST A. COBURN, *Secretary*.

Boston Society of Civil Engineers.

MAY 15, 1895.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.45 o'clock, p.m., President Albert F. Noyes in the chair. Seventy-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Arthur A. Fobes, Philip Marquand, Walter W. Patch, and Hartley L. White, were elected members of the Society.

The Secretary reported for the Board of Government that it had voted to continue the Committee on Weights and Measures with the following membership : Charles T. Main, Allen Hazen and Dwight Porter. The Board also recommended that the communications in relation to a standard of thickness for metals, from the American Society of Mechanical Engineers, and from the Engineers' Club of St. Louis, be referred to the Committee on Weights and Measures for its consideration and that the Committee be requested to report to the Society what action it deemed advisable. On motion the recommendation of the Board was adopted.

The Secretary read a circular letter from the Board of Direction of the Western Society of Engineers addressed to the several societies, members of the Association of Engineering Societies, relating to the cost of the JOURNAL. On motion it was voted to refer the letter to the members of the Board of Managers representing the Boston Society for answer.

The Secretary read a letter from the Committee of the American Society of Mechanical Engineers on Standard Thicknesses for Gauges, transmitting a blue print showing proposed decimal gauge. The communication was referred to the Committee on Weights and Measures.

A letter was read from Mr. E. L. Corthell, a member of the Society, enclosing a report of the Mexican Association of Engineers and Architects, in relation to the formation of an International Institute of Engineers and Architects. The letter and report were referred to the Board of Government.

On motion of Mr. Brooks, it was voted to appropriate the sum of \$225.06 for the payment of the special assessment for 1894, of the Association of Engineering Societies as per bill dated April 22, 1895.

Mr. J. Parker Snow then read a paper entitled "Wooden Bridge Construction on the Boston & Maine Railroad." The paper was discussed by Messrs Guppy and Rice.

Mr. R. S. Hale followed with a paper entitled "Approximate Analysis of the use of Coal in an Edison Electric Station of the Type Standard About 1890," which was discussed in a short paper by Mr. George H. Barrus, read by the Secretary. Adjourned.

S. E. TINKHAM, *Secretary.*



Bradley & Poates, Engrs, N.Y.

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XIV.

JUNE, 1895.

No. 6.

PROCEEDINGS.

The Civil Engineers' Club of Cleveland.

CASE LIBRARY BUILDING, CLEVELAND, OHIO, MAY 11, 1895.—The regular meeting of the Civil Engineers' Club, Tuesday evening, June 11, 1895, was called to order by President Mordecai. There were present thirty-two members and visitors. The minutes of the last meeting were read and approved. The application for admission as active member by Richard Hoffman, C.E., was read.

President Mordecai announced the death of a former member of the Society, Mr. A. M. Wellington. Mr. James Ritchie moved that a committee of three be appointed to draw up proper resolutions in regard to his death. Mr. Thompson spoke feelingly in regard to Mr. Wellington, and the motion was carried.

It was moved by Mr. Culley and carried that a committee of seven be appointed to arrange for a picnic.

The Club then listened to the paper of the evening by Mr. Frank Aborn, entitled, "Some Facts Concerning Drawing for Engineers."

Mr. Aborn spoke of drawing, as a natural language, a method of expression. He compared dimension and pictorial drawing; showed the value of the latter, and the obstacles to its acquisition, and that skill is to be acquired by intelligently directed effort in freehand drawing.

It was a very interesting paper. The practical importance of this increasing and valuable means of communicating ideas, and the simple method of acquiring skill by freehand practice, were illustrated in a clear, practical manner.

Remarks were offered by Messrs. Benjamin, Herman, Culley, and others, after which the President appointed, as committee upon resolutions upon the death of Mr. Wellington, Messrs. Thompson, Ritchie and Searles.

As Committee on Picnic, Messrs. Gobielle, Culley, Warner, Jewett, Miller, Thompson and Beardsley.

The meeting adjourned.

F. A. COBURN, *Secretary*.

Engineers' Club of St. Louis.

419TH MEETING, JUNE 5, 1895.—The Club was called to order by President Russell at 8.25 P.M., at 1600 Lucas Place. Eighteen members and five visitors present.

The minutes of the 418th meeting were read and approved. The Executive Committee reported the doings of its 191st meeting, announcing that arrangements had been made for a meeting of the Club on June 19th, on which date Mr. H. A. Wheeler will present a paper on "Vitrified Brick for Street Paving."

Applications for membership were announced as follows: Clinton Kimball, assistant engineer, Bell Telephone Company, of Missouri; John J. Lichter, Jr., engineer Union Depot Railway Company; H. H. Sykes, chief engineer, Bell Telephone Company, of Missouri.

Mr. Bryan stated that a meeting of the local membership of the American Society of Mechanical Engineers had been held, the unanimous sentiment of which was, that arrangements be made to invite the Association to hold its Spring meeting of 1896 in St. Louis, and it was thought that the movement would be strengthened by being indorsed by the Engineers' Club of St. Louis. On motion of Mr. Moore, it was ordered that the Executive Committee extend, on behalf of the Engineers' Club of St. Louis, an invitation to the American Society of Mechanical Engineers, to hold their Spring meeting of 1896 in St. Louis.

President Russell stated that the settling basins at the Chain of Rocks would soon be cleaned, and invited the Club to visit the works. Mr. Holman extended a formal invitation to the Club to visit the works on the afternoon of Saturday, 15th inst. Mr. Crosby stated that he would make arrangements for the transportation of the Club. Ordered that the invitations be accepted, and that the Executive Committee complete the necessary arrangements.

Mr. Edward Flad then addressed the Club on the subject of standpipes, making special reference to a tower designed by him and just completed at St. Charles, Mo. Its dimensions were 25' in diameter by 70' high; capacity 250,000 gallons. It was encased in brickwork tied to the tower itself. The standpipe was stiffened by six circular girders, the object of which was to maintain the circular shape of the tower, so as to afford maximum strength to resist wind pressure. These girders were on the outside of the tank, occupying the space of 2' between the tower itself, and the casing. A stairway was also placed in this space. The standpipe was covered by a roof of iron and slate. Due attention had been given to architectural features. The cost of the stand-pipe was: for iron work, \$4,450; brick work, \$2,807; foundation, \$677, total \$7,934. Mr. Flad also showed a tower designed by him for Laredo, Texas. He showed stereopticon views of the St. Charles, Laredo, and other towers of recent design, as well as a number of towers which had failed.

Messrs. Johnson, Holman, Baier, Bryan, Gayler, Moore, and Crosby, took part in the discussion. Adjourned.

WILLIAM H. BRYAN, *Secretary*.

420TH MEETING, JUNE 19, 1895.—The Club was called to order at 8.30 P.M., by Vice-President Ockerson, at 1600 Lucas Place, seventeen members and nine visitors present. The minutes of the 419th meeting were read and approved, as also a brief record of the excursion of 15th inst. The Executive Committee reported favorably on the applications for membership of Messrs. Clinton Kimball, J. J. Lichter, Jr., and H. H. Sykes. They were balloted for and elected.

On motion of Mr. Hermann, votes of thanks were unanimously tendered to Messrs. W. C. Brown and B. L. Crosby, of the Burlington System and to Water Commissioner Holman for courtesies extended in connection with the excursion to Chain of Rocks and Bellefontaine Bridge on 15th inst.

Mr. H. A. Wheeler then addressed the Club on the subject of "Vitrified Brick

for Street Paving." This material had been used in Holland for over a century, and in the North of England for a slightly shorter period. In Charleston, West Virginia, it had been in use for twenty-five years, and in Bloomington, Illinois, for twenty years, since which time its use has greatly increased, it now being employed in some four hundred cities and towns in this country. This year marks its adoption in the larger and more conservative cities of St. Louis, Chicago and New York. Mr. Wheeler gave a definition of the term "vitrified" brick, and explained the process of manufacture, the material used, and exhibited numerous samples. The clays employed were: the superficial, or common earth; the shales; and the impure fire clays. The first is so difficult of treatment that its use is now rare. The shales furnish the best and most commonly used material. The fire clays, however, were frequently employed satisfactorily. A necessity of prime importance is slow cooling of the kilns. It is now quite possible to secure a paving brick of high grade, providing engineers will insist upon quality, and pay a price which will warrant greater care in every detail of manufacture, and more time in cooling. Laboratory tests are frequently misleading. Satisfactory inspection can be made at the yard by an experienced man simply by the eye and the hammer. Tests made in the laboratory covered the crushing, crossbreaking, absorption, and the tumbling of brick in a foundry rattler. Mr. Wheeler suggested that it would be well to add tests of density and hardness. The uses of these brick were for foundations, sewers and street paving, for which latter place the speaker believed them to possess important advantages over all other material, being harder than granite. The use of vitrified brick for streets and sewers would permit the cleaning of the streets by the hydraulic system.

The discussion was participated in by Messrs. Kinealy, Crosby, Chauvenet, Baier, Harrington and Ockersman. Adjourned.

WILLIAM H. BRYAN, *Secretary*.

Technical Society of the Pacific Coast.

REGULAR MEETING HELD JUNE 7, 1895. Called to order by Vice-President Curtis.

The minutes of the last regular meeting were read and approved.

After a ballot, Mr. Edward S. Cobb was elected to membership in the Society.

The Secretary read a letter, announcing the death of Mr. George Beardsley, a member, of Phoenix, Arizona.

The Chair appointed Messrs. C. E. Grunsky and D. C. Henny a committee to draw suitable resolutions in memory of the deceased member.

President George W. Dickie read a paper, entitled "Engineers; Consulting, Inspecting and Contracting; Their Relationship to each Other and to the Public," which was opened for discussion, and viewed from different standpoints by the members present. Adjourned.

OTTO VON GELDERN, *Secretary*.

Montana Society of Civil Engineers.

HELENA, MONT., JUNE 8, 1895.—The regular monthly meeting of the Montana Society of Civil Engineers was held on Saturday evening, June 8th, at the Society's rooms, in the Denver Block, on Broadway. President Keerl called the meeting to order, the following members being present: James S. Keerl, William

A. Haven, A. E. Cumming, A. S. Hovey, Walter S. Kelley and F. J. Smith. The minutes of the last regular meeting were read and approved.

The President then appointed Messrs. Haven and Cumming tellers to canvass the ballots for admission to membership, and upon completion of the count the President announced that Frederick J. Taylor had been unanimously elected a member of the Society.

The committee, consisting of Messrs. Haven and Goodale, appointed to investigate the cost of publishing the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, then made an exhaustive report in writing, which gave evidence that the matter had been thoroughly investigated in all its details. The report had reference particularly to the circular letter of the Western Society of Engineers, and the committee stated that it found no basis for some of the statements in that letter relative to an "apparent excessive cost of the JOURNAL for 1895." The report was accepted as being the sense of the Society, and the Secretary was directed to send a copy of it to Prof. J. B. Johnson, chairman of the Board of Managers of the Association.

A. E. Cumming, chairman of the committee appointed to prepare blanks for quartz lode and placer location notices, to conform to the new law which goes into effect July 1st, reported that the committee had spent considerable time in looking up the law, etc. He called the attention of the members present to the various important requirements in the new law, and submitted to the meeting the blank forms of location notices as prepared by the committee. He also stated that he had submitted these blanks to a prominent attorney for inspection and that the attorney had pronounced them all right. A motion prevailed that the report be accepted, that the blanks as prepared by the committee be adopted and that the Secretary be instructed to have a sufficient number of these blanks printed to send to all the publishers in the mining districts of the State, and to each member of the Society. The Society hopes that these blanks will meet with the approval of the various publishers, and that these forms will be adopted, thus securing uniformity throughout the State.

A committee of one, consisting of James S. Kcerl, was appointed to confer with the librarian of the public library as to the most desirable books on engineering to be purchased for the library.

A paper on the Cost of Steam and Water Power, Montana, prepared by Maurice S. Parker, of Great Falls, was then read by the Secretary. This paper was a most interesting one. It contained tables showing the cost per horse-power per day and per year, produced by steam and water. The remarkable cheapness of the cost of producing power by water, as compared with steam, left little room for doubt that in Montana, with her mountain torrents, steam will soon take second place. The paper throughout showed that the author was thoroughly familiar with his subject.

After discussion of the subject by all the members present the meeting adjourned.

FORREST J. SMITH, *Secretary*.

Boston Society of Civil Engineers.

JUNE 12, 1895.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 8.30 o'clock, P.M., President Albert F. Noyes in the chair. Number of members and visitors present, including ladies, eighty-six.

On motion it was voted to dispense with the reading of the record of the last meeting.

Messrs. George W. Fuller, Frank O. Melcher and Sanford E. Thompson were elected members of the Society.

The President and Treasurer were authorized to change the Society's rooms, provided the increased cost per year does not exceed one dollar per member.

The thanks of the Society were voted to the trustees of the Massachusetts General Hospital Association and to the officials of the New York, New Haven and Hartford Railroad Company, for courtesies shown members of the Society on the occasions of the excursions on May 15 and June 12, 1895.

Mr. F. O. Whitney, for the committee appointed to prepare a memoir of Adelbert L. Sprague, submitted its report, which was read and accepted.

Mr. Main, for the committee on weights and measures, presented the following resolution:

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal or other trade gauges now in vogue, and strongly urge the use of one-thousandths of an inch for all kinds and classes of small measurements. On motion it was voted to print the report of the committee in the notice of the September meeting and to defer action on the report until that meeting.

A paper by Francis C. Tucker was then presented, giving the engineering history of a lawsuit growing out of a contract for building a portion of the Grand Island & Wyoming Central Railroad, through the Black Hills of South Dakota. It was voted to print the paper in the JOURNAL with such discussions as may be offered.

The rest of the evening was devoted to the exhibition of a series of beautiful lantern views presented by Mr. FitzGerald and President Noyes.

Adjourned.

S. E. TINKHAM, *Secretary*.

Western Society of Engineers.

The 327th meeting was held in the Society's rooms on Wednesday, April 3, 1895, at 8 P.M. President Horton in the chair, and 62 members and guests present.

The minutes of the annual meeting were approved as printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The minutes of the March meeting were read and approved.

The Secretary reported for the Board of Directors—About ninety volumes of periodicals are being bound for the library.

The application of Mr. Charles F. White, of Chicago, for membership in the Society, was filed March 19, 1895.

The Secretary was instructed to have printed 1,000 copies of the Constitution, By-Laws and List of Members.

April 2, 1895, the following named gentlemen were elected to membership in the Society: As members—Messrs. George M. Basford, C. V. Brainard, William S. Dawley, Nicholas D. Pound, Leonard Sewall Smith, George E. Waldo, Charles F. White and Edward Dana Wickes. As associates—Messrs. George Horace Bryant and Charles F. Quincy. The application of William D. Pickels, as member, and William Edmund Syer, as junior, both of Chicago, were received and placed on file.

The death of Mr. Warren Collier Smith, a member of the Society, was announced, and on motion the President appointed Messrs. Isham Randolph, Frederic S. Brown and James J. Reynolds a committee to prepare a memorial of the deceased member.

A letter from Mr. E. L. Corthell, from Berne, Switzerland, in acknowledgment

of the cablegram sent him by the Society, at the annual banquet, was read by the Secretary.

Messrs. Frank C. Hatch, John Saltar, Jr., and H. F. J. Porter, were appointed a committee on "Standard Gauges for Thickness of Metals," in conformity with a request of the Engineers' Club of St. Louis.

Mr. R. H. Bethel was appointed on the Committee on Excursions and Entertainment, *vice* Mr. James J. Reynolds resigned.

The meeting was interspersed with vocal music and the "Club Smoker" with its concomitant features, all of which seemed to be very fully enjoyed. At a late hour the meeting adjourned.

At the meeting of the Board of Directors, held April 16, 1895, applications for membership in the Society were received and placed on file, as follows: As members—Louis K. Comstock and Howard Berge, both of Chicago. As Associate—Francis W. Lane, Chicago.

A special meeting (328th of the Society) was held in Science Hall, Armour Institute, Chicago, on Wednesday, April 17, 1895, at 8 P.M. Vice-President Morehouse in the chair and 82 members and guests present.

The Committee on Excursions and Entertainments, through its chairman, Mr. Appleton, outlined a very attractive list of proposed excursions, the next one to occur on April 27th.

Mr. Horace E. Horton read a paper, "The Highway Bridges Across the Mississippi River," illustrated by many lantern views, and accompanied by interesting notes of the various bridges, as the views were presented.

After discussion, the meeting adjourned.

CHARLES J. RONEY, *Secretary*.

The 329th meeting of the Society was held in the Society's rooms on Wednesday, May 1, 1895, at 8 P.M. Vice-President Morehouse in the chair, and about 35 members and guests present. The minutes of the February meeting were approved as printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. The minutes of the April meetings were approved as printed.

The Secretary reported for the Board of Directors—The following applications for membership were filed April 16, 1895. As Members—Louis K. Comstock and Howard Berge, both of Chicago. As Associate—Francis W. Lane, Chicago. On April 30th the following persons were elected: As Members—Howard Berge, Louis K. Comstock and William D. Pickels. As Junior—William Edmund Syer. As Associate—Francis W. Lane.

The application of Casper L. Redfield as Member and of Norwood De Hart as Junior were filed April 30, 1895.

Mr. Gerber, for the Committee on Excursions and Entertainments, announced arrangements for an inspection trip over the Metropolitan West Side Elevated R. R., and visit to the Power House, for Saturday, P.M., May 18, 1895.

Mr. Chanute, for the Committee on Library, asked for suggestions from members as to the best disposition to be made of a balance of the Library fund, amounting to about \$75.

Mr. Chanute presented a resolution regarding a simultaneous reading and discussion by the various Societies in the Association of Engineering Societies of valuable papers originating in any of the Societies.

The resolution was referred to the Board of Directors for consideration and report to the Society at the regular meeting in June.

The following resolution, presented by Mr. James J. Reynolds, was unanimously adopted :

"Resolved, That this Society learns with regret the recent death of Gen. John Newton, in New York, and hereby places on record its sense of the loss thus sustained by the engineering profession and its high appreciation of his distinguished services."

By vote, the date for the next meeting at Armour Institute was changed from the third Wednesday in the month to the preceding Tuesday, 14th instant.

The question as to what grade or grades of members are entitled to wear the badge of the Society was referred to the Board of Directors for recommendations.

The 330th meeting of the Society was held in Science Hall, Armour Institute, at 8 P.M. Tuesday, May 14, 1895, President Horton in the chair; 36 members and guests present.

The paper of the evening, "The De Kalb, Ill., Municipal Electrical Pumping Plant," was read by the author, Mr. Daniel W. Mead, and was illustrated by lantern views. The reading of the paper was followed by an extended and animated discussion, and the meeting adjourned at a late hour.

On Saturday afternoon, May 18th, through the courtesy of the officials of the Metropolitan West Side Elevated R. R. Co., about 108 members and guests assembled at the Franklin Street terminus of this road and, after an inspection of the bridge over the South Branch, boarded a special train at 2.30 P.M. for a trip over the main line to West 48th Street, inspecting the Power House on the return trip.

CHARLES J. RONEY, *Secretary*.

The 331st meeting of the Society was held in the Society's rooms, 1737 Monadnock Block, Chicago, on Wednesday evening, June 5, 1895. President Horton in the chair; about fifty-five members and guests present.

The minutes of the meetings and report of the excursion of the previous month were read and approved.

The Secretary reported for the Board of Directors: At the meeting of the Board of Directors held June 4, 1895, Mr. Casper L. Redfield was elected a Member, and Mr. Norwood De Hart was elected a Junior.

The resolution offered by Mr. Chanute at the regular May meeting of the Society and referred to the Board, relating to simultaneous reading and discussion of papers in the participating societies of the Association, was considered, and it was voted that it was inexpedient to act on this resolution pending the report of the Board of Directors concerning the management of the JOURNAL, to be presented to the Society at the June meeting.

It was also voted that the blue badge of the Society should be worn by the grades of Members and Honorary Members only, and that Associates or Juniors may wear badges of the design, but in red enamel.

The action thus taken is presented as the recommendation of the Board in these matters.

Mr. Morehouse presented the following report of a Special Committee of the Board, which was accepted by the Board of Directors and is now presented to the Society.

The Secretary then read the communication which, in part, is as follows :

Your Board of Directors believe that the Association should be restricted in the unlimited powers at present conferred upon it, and, to that end, now makes to this Society the following recommendations as rules hereafter to be observed in the publication of the JOURNAL :

1. The object of the JOURNAL is to print the papers and transactions of the Societies, and it is not for the purpose of establishing a professional monthly magazine.

2. The amount of matter must be restricted to that which can be published at a cost of \$3.00 per annum for each person on the mailing list of each Society, except as hereinafter provided.

3. The amount of matter which each Society is entitled to have published to be in direct proportion to the amount it contributes to the cost of publication.

4. Any Society desiring to publish matter in excess of its proportion, may publish such matter by paying the full extra cost thereof.

5. No Society having dues or assessments in arrears for more than 90 days after notice, or whose arrearages shall at any time exceed \$2 per member, shall participate in the privileges of the Association ; nor shall it be in the power of the Board of Managers to deviate from enforcing this rule.

6. A paper shall be accredited to the Society before which it is read, but the author, if a member of any Society or Societies of the Association shall be credited with such membership and none other.

7. The Association shall not have power to make any contracts or incur any liabilities which will bind the Association to an expenditure beyond the limitations specifically permitted by the Articles of Association.

8. The Secretary of the Association shall not have authority to edit any papers sent for publication, except by specific consent of the Society furnishing the paper.

9. Advertisements may be received by and inserted in the JOURNAL by its management, but all contracts therefor must terminate in the calendar year of the contract.

10. The Association shall not publish in the JOURNAL any other matter than the papers and transactions of the Societies, if it shall appear that by so doing the cost will exceed \$3.00 per annum per member of the Societies.

11. The Association may secure subscriptions to the JOURNAL, and furnish reprints, with a view to profit to the Association.

The above recommendations are based on the principle that the cost of the JOURNAL must not exceed \$3.00 to each member of the Societies, and that the amount of matter must be restricted to that which can be published for that amount, and that the amount of matter at the disposition of any Society is in proportion to the amount of money paid by that Society to the Association.

Mr. Morehouse spoke at length in favor of the adoption by the Association of Engineering Societies of the above recommended rules, and by request the Secretary read a letter from Chairman J. B. Johnson to the members of the Board of Managers of the Association of Engineering Societies, under date of May 29, 1895, regarding certain matters concerning the JOURNAL.

The subject of the above report was discussed by Messrs. Ward, Morehouse, Condon, Mead, Reynolds, Liljencrantz, R. P. Brown and Thos. T. Johnston, and the following resolution was unanimously adopted :

" *Resolved*, That the recommendations for rules hereafter to be observed in the

publication of the JOURNAL, as presented to the Society this evening by the Board of Directors be concurred in by the Society, and that these recommended rules be forwarded to the Board of Managers of the Association of Engineering Societies as the expressed opinion of this Society, and that the representatives of this Society on the Board of Managers be instructed to present these rules to the Board of Managers for adoption."

The recommendation of the Board of Directors in regard to the Society badge was adopted.

It was voted that the thanks of the Society be extended to Mr. James R. Chapman and Mr. W. E. Baker, for courtesies extended to the Society on the occasion of its recent inspection trips to the power-house of the North Chicago Electric Transit Co., and over the line of the Metropolitan West Side Elevated Railroad, respectively.

Prof. Hatch, Chairman of the Committee on Standard Gauges for Thickness of Metals, reported progress.

On motion it was *Resolved*, That the Board of Managers of the Association of Engineering Societies be requested to make to this Society a financial statement for the first quarter of the present year, and for each quarter thereafter, showing the cost of the JOURNAL, the number of members in each Society on the JOURNAL mailing list, the amount of money paid by each Society, and the amount any Society is delinquent.

It was voted that the regular meetings during the months of July and August be omitted.

Adjourned.

CHARLES J. RONEY, *Secretary*.



Bradley & Postes, Engr's, N.Y.

INDEX TO CURRENT LITERATURE.

In this department is given an Index of current periodical engineering literature. To each title is appended a short note indicating the character of the article indexed. The index notes are printed on but one side of the paper, so that the titles may be cut out and pasted upon cards or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

All readers of the JOURNAL are requested to aid in making this Index as complete as possible. Notices for this department, and all matter to be indexed, should be sent to J. B. JOHNSON, Manager of Index Department, Washington University, St. Louis, Mo.

LIST OF PERIODICALS INDEXED.

Following the title of each periodical is given, in italics, the abbreviation by which it is referred to in the Index.

For alphabetical list of abbreviated titles, see page vii.

UNITED STATES.

ANNUAL.

- American Institute of Mining Engineers, Transactions of the —** (*Trans. A. I. M. E.*), 13 Burling Slip, New York; per year, \$5.
American Society of Mechanical Engineers, Transactions of the — (*Trans. A. S. M. E.*), 12 West Thirty-first Street, New York.
American Water Works Association, Proceedings of Annual Meetings of the — (*Am. W. W. Ass'n.*), 95 William Street, New York; per year, \$1.
Society of Naval Architects and Marine Engineers, Transactions of the — (*Trans. N. A. & M. E.*), W. L. Capps, Secretary, 1710 F Street N. W., Washington, D. C.; \$10 per annual volume.

QUARTERLY.

- Engineers' Club of Philadelphia, Proceedings of the —** (*Proc. Eng. Club Phila.*), 1122 Girard Street, Philadelphia, Pa.; per year, \$2.
New England Water Work Association, Journal of the — (*Jour. N. E. W. W. Assn.*), New London, Conn.; per year, \$2; single copies, 75 cents.
School of Mines Quarterly (*Sch. Mines Quart.*), Columbia College, New York City; per year, \$2; single copy, 50 cents.
Technology Quarterly and Proceedings of the Society of Arts (*Tech. Quart.*), Massachusetts Institute of Technology, Boston, Mass.; per year, \$3.
United States Naval Institute, Proceedings of the — (*Proc. U. S. N. I.*), United States Naval Institute, Annapolis, Md.; per year, \$3.50; single copy, \$1.

MONTHLY.

SOCIETIES.

- American Institute of Electrical Engineers, Transactions of the —** (*Trans. A. I. E. E.*), 12 West Thirty-first Street, New York City.
American Society of Civil Engineers, Transactions of the — (*Trans. A. S. C. E.*), 127 East Twenty-third Street, New York; per year, \$10.
Association of Engineering Societies, Journal of the — (*Jour. Assn. Eng. Socs.*), Philadelphia; per year \$3; single copy, 30 cents.
Engineers' Society of Western Pennsylvania, Proceedings of — (*Proc. Eng. Soc. W. Pa.*), Allegheny, Pa.; per year, \$7; single copy, 75 cents.
Franklin Institute, Journal of the — (*Jour. Frank. Inst.*), Franklin Institute, Philadelphia, Pa.; per year, \$5; single copy, 50 cents.

Continued on page iii

The Weir Frog Co.'s

AUTOMATIC

HIGH SWITCH STAND

We show herewith our latest improvement in Automatic Safety Switch Stands, and introduce something entirely new in this line of track devices.

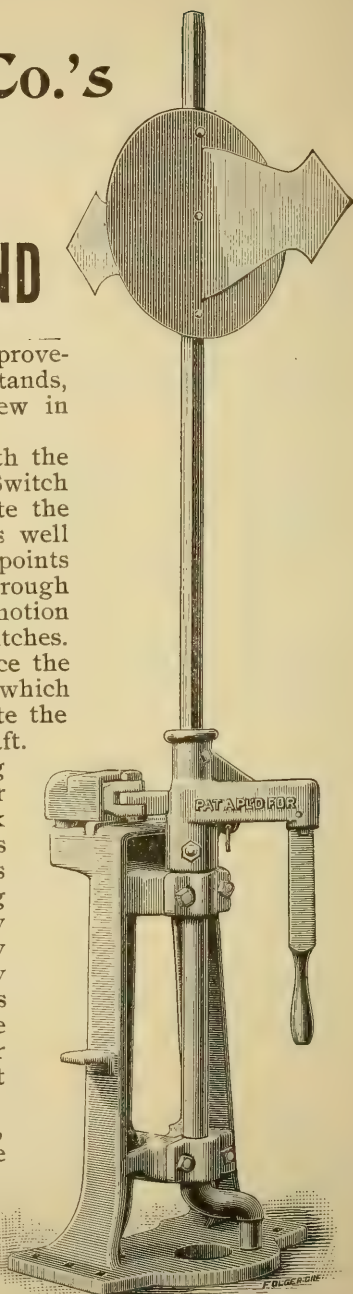
It will be noticed we do away with the Clutch feature of other Spring Switch Stands, and in doing so we eliminate the weak point of these Stands, as it is well known the latter are apt to leave the points partially open after train has trailed through the switch; and we also avoid the lost motion due to the excessive wear of the clutches.

On the top of our Stand we place the Spring enclosed in a housing, through which we connect sliding bars which actuate the lever casting fastened to the crank shaft.

The Spring acting upon the sliding bars is always bearing against the lever casting, thus pushing over the crank shaft which forces the switch points tight up against the stock rails, and as there are no stops or clutches confining the movement of the crank shaft, any lost motion, due to wear of parts, or by widening of gauge, is overcome by increased throw of crank, and thus avoiding the possibility of a *lip* to the Switch. This is the chief and peculiar feature of our new Stand, and is not accomplished by any other.

This Stand is well proportioned, and has fewer parts, which are more easily gotten at than any other make of Spring Stands.

We also make a Low Stand for yard purposes, differing only in height from the High Stand.



List of Periodicals Indexed—Continued.

MONTHLY—Continued.

PERIODICALS.

- American Engineer and Railroad Journal** (*Am. Eng. & R. R. Jour.*), 47 Cedar Street, New York; per year, \$3; single copy, 25 cents.
- Cassier's Magazine** (*Cassier*), World Building, New York; per year, \$3; single copy, 25 cents.
- Clay Worker** (*Clay W.*), Indianapolis, Ind.; per year, \$2.00.
- Engineering Magazine** (*Eng. Mag.*), 47 Times Building, New York; per year, \$3; single copy, 25 cents.
- Engineering Mechanics** (*Eng. Mech.*), 430 Walnut Street, Philadelphia, Pa.; per year, \$1; single copy, 10 cents.
- Irrigation Age** (*Irrigation Age*), Chicago, Ill.; per year, \$2.
- Master Steam Fitter** (*Mst. Stm. Fitter*), 218 La Salle Street, Chicago, Ill.; per year, \$1; single copy, 10 cents.
- Paving and Municipal Engineering** (*Pav. & Munic. Eng.*), Municipal Engineering Co., 44 Chamber of Commerce, Indianapolis, Ind.; per year, \$2; single copy, 25 cents.
- Power** (*Power*), World Building, New York; per year, \$1; single copy, 10 cents.
- Railway Engineering and Mechanics** (*Ry. E. & M.*), 816 The Rookery, Chicago, Ill.; per year, \$1; single copy, 10 cents.
- Safety Valve** (*Sy. Valve*), 55 Liberty Street, New York; per year, \$1; single copy, 10 cents.
- Street Railway Journal** (*St. Ry. Jour.*), World Building, New York; per year, \$4; single copy, 35 cents.
- Stone** (*Stone*), Chicago; per year, \$2; single copy, 25 cents.
- Street Railway Review** (*St. Ry. Rev.*), 269 Dearborn Street, Chicago, Ill.; per year, \$2; single copy, 25 cents.

WEEKLY.

- American Architect** (*Am. Arch.*), Ticknor & Co.; 211 Tremont Street, Boston, Mass.; single copy, 15 cents.
- American Machinist** (*Am. Mach.*), 96 Fulton Street, New York; per year, \$2; single copy, 10 cents.
- Boston Journal of Commerce** (*Bos. Jour. Com.*), 128 Purchase Street, Boston, Mass.; per year, \$3; single copy, 6 cents.
- Electrical Engineer** (*Elec. Engr.*), 203 Broadway, New York; per year, \$3.
- Electrical World** (*Elec. World*), 177 Times Building, New York; per year, \$3; single copy, 10 cents.
- Engineering and Mining Journal** (*E. & M. Journal*), 253 Broadway, New York; per year, \$5; single copy, 15 cents.
- Engineering News** (*Eng. News*), Tribune Building, New York; per year, \$5; single copy, 15 cents.
- Engineering Record** (*Eng. Rec.*), 277 Pearl Street, New York; per year, \$5; single copy, 12 cents.
- Railroad Gazette** (*R. R. Gaz.*), 73 Broadway, New York; per year, \$4.20; single copy, 10 cents.
- Scientific American Supplement** (*Sci. Am. Sup.*), 361 Broadway, New York; per year, \$5; single copy, 10 cents.
- Street Railway Gazette** (*St. Ry. Gaz.*), Monadnock Block, Chicago; per year, \$3; single copy, 25 cents.

CANADA.

- Canadian Society of Civil Engineers, Transactions of the** — (*Trans. Can. Soc. C. E.*), McGill University, Montreal.

GREAT BRITAIN.

- Electrical Review** (*Elec. Rev.*), 22 Paternoster Row, London, E. C.; weekly; per year, 21s, 8d; single copy, 4d.
- Engineer, The** — (*Lon. Engineer*), London, England; weekly; per year, \$10; single copy, 25 cents.
- Engineering** (*Lon. Eng.*), London, England; weekly; per year, \$10; single copy, 25 cents.
- Engineering Review** (*Eng. Rev.*), 29 Great George Street, S. W., England; monthly; single copy, 6d.
- Institution of Civil Engineers, Proceedings of the** — (*Proc. Inst. C. E.*), 25 Great George Street, Westminster, S. W., London, England.

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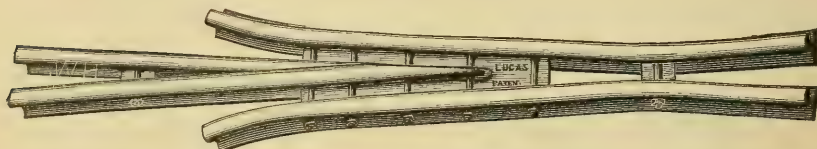
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WEEKLY.—Concluded.

Institution of Mechanical Engineers, Proceedings of the — (*Proc. Inst. Mech. Engs.*), 19 Victoria Street, Westminster, S. W., London, England.

Mechanical World (*Mech. World*), Manchester, England; weekly; per year, 8s, 8d.

Practical Engineer (*Prac. Engr.*), 2 Amen Corner, London, E. C., England; weekly; per year 10s.

Railway Engineer (*Ry. Eng.*), 8 Catherine Street, Strand, W. C., London, England; monthly; single copy, 1s

INDIA.

Indian Engineer (*Ind. Engr.*), Calcutta, India; per year, 20 Rs.

Indian Engineering (*Ind. Engng.*), Calcutta, India, weekly; per year, 18s; single copy, 8 annas.

FRANCE.

Ponts et Chaussees, Annales des — (*Annales des P. & C.*), monthly, Vve. Ch. Dunod, 49 Quai des Augustins, Paris, France.

Société des Ingénieurs Civils, Mémoires de la — (*Méms. Soc. Ing. Civils*), monthly, 10 Cité Rougement, Paris.

GERMANY, AUSTRIA AND SWITZERLAND.

Archiv für Eisenbahnwesen (*Arch. f. Eisenbw.*), bi-monthly, Julius Springer, Berlin, Germany; per year, 12 marks.

Civilingenieur, Der — (*Civ. Ing.*), monthly.

Deutsche Bauzeitung (*Deutsche Bztg.*), semi-weekly, Berlin, Germany; per year, 12 marks.

Journal für Gasbeleuchtung und Wasserversorgung (*Jour. f. Gasb. u. Wasserv.*), three times a month, 11 Glückstrasse, Munich, Germany; per year, 20 marks.

Praktische Maschinen-Constructeur, Der—(*Pr. Msch. Cnstr.*), bi-weekly, Leipzig-Gohlis, Germany; per year, 16 marks.

Schweizerische Bauzeitung (*Schw. Bztg.*), German and French, 32 Brandschenkestrasse, Zurich.

Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins (*Ztsch. Oest.*), weekly.

Zeitschrift des Vereines Deutscher Ingenieure (*Ztsch. Ver. Ing.*), weekly, Berlin, Germany; per year, 32 marks.

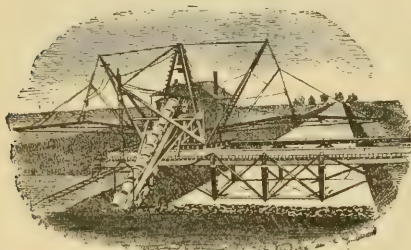
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- Am Arch.** *American Architect*, Boston; weekly.
- Am Eng & R R Jour.** *American Engineer & Railroad Journal*, New York; monthly.
- Am Mach.** *American Machinist*, New York; weekly.
- Am. W. W. Assn.** *Proceedings, American Water Works Association*, New York; annual.
- Annales des P & C.** *Annales des Ponts et Chaussées*, Paris, France; monthly.
- Arch f Eisenbw.** *Archiv für Eisenbahnwesen*, Berlin, Germany; bi-monthly.
- Bos. Jour. Com.** *Boston Journal of Commerce*, Boston, Mass.; weekly.
- Cassier.** *Cassier's Magazine*, New York; monthly.
- Civ Ing.** *Der Civilingenieur*; monthly.
- Clay W.** *Clay Worker*, Indianapolis, Ind.; monthly.
- Deutsche Bztg.** *Deutsche Bauzeitung*, Berlin, Germany; semi-weekly.
- E & M Journal.** *Engineering and Mining Journal*, New York; weekly.
- Elec Eng.** *The Electrical Engineer*, New York; weekly.
- Elec Rev.** *Electrical Review*, London, Eng.; weekly.
- Elec World.** *The Electrical World*, New York; weekly.
- Eng Mag.** *The Engineering Magazine*, New York; monthly.
- Eng Mech.** *Engineering Mechanics*, Philadelphia, Pa.; monthly.
- Eng News.** *Engineering News*, New York; weekly.
- Eng Rec.** *Engineering Record*, New York; weekly.
- Eng Rev.** *Engineering Review*, London, Eng.; monthly.
- Ind Engng.** *Indian Engineering*, Calcutta, India; weekly.
- Ind. Engr.** *Indian Engineer*, Calcutta, India; weekly.
- Irrigation Age.** *The Irrigation Age*, Chicago, Ill.; monthly.
- Jour Assn Eng Soc.** *Journal of the Association of Engineering Societies*, Philadelphia; monthly.
- Jour f Gasb u Wasserv.** *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Germany; three times a month.
- Jour Frank Inst.** *Journal of the Franklin Institute*, Philadelphia, Pa.; monthly.
- Jour NEW W Assn.** *Journal of the New England Water Work Association*, New London, Conn. quarterly.
- Lon Eng.** *Engineering*, London, England; weekly.
- Lon Engineer.** *The Engineer*, London, England; weekly.
- Mst. Stm. Fitter.** *Master Steam Fitter*, Chicago, Ill.; monthly.
- Mech World.** *The Mechanical World*, Manchester, England; weekly.
- Mems Soc Ing Civ.** *Mémoires de la Société des Ingénieurs Civils*, Paris; monthly.
- Pav & Munic Eng.** *Paving and Municipal Engineering*, Indianapolis, Ind.; monthly.
- Power.** *Power*, New York; monthly.
- Pr Mach Constr.** *Der Praktische Maschinen-Constructeur*, Leipsic.
- Prac. Engr.** *Practical Engineer*, London; weekly.
- Proc Eng Club Phila.** *Proceedings of the Engineers' Club of Philadelphia*, Philadelphia, Pa.; quarterly.
- Proc Eng Soc W Pa.** *Proceedings of Engineers' Society of Western Pennsylvania*, Pittsburg, Pa.; monthly.
- Proc Inst C E.** *Proceedings of the Institution of Civil Engineers*, London, England
- Proc Inst Mech Engrs.** *Proceedings of the Institution of Mechanical Engineers*, London, England.
- Proc U S N I.** *Proceedings of the United States Naval Institute*, Annapolis, Md.; quarterly.
- R R Gaz.** *Railroad Gazette*, New York; weekly.
- Ry E & M.** *Railway Engineering and Mechanics*, Chicago, Ill.; monthly.
- Ry Eng.** *The Railway Engineer*, London, England; monthly.
- Sch Mines Quart.** *School of Mines Quarterly*, New York City.
- Schw Bztg.** *Schweizerische Bauzeitung*, Zurich; German and French; weekly.
- Sci Am Sup.** *Scientific American Supplement*, New York; weekly.
- Stone.** *Stone*, Chicago, Ill.; monthly.
- St Ry Gaz.** *The Street Railway Gazette*, Chicago, Ill.; weekly
- St Ry Jour.** *Street Railway Journal*, New York; monthly.
- St Ry Rev.** *Street Railway Review*, Chicago, Ill.; monthly.
- Sy Valve.** *Safety Valve*, New York; monthly.
- Tech Quart.** *Technology Quarterly and Proceedings of the Society of Arts*, Boston, Mass
- Trans A I E E.** *Transactions of the American Institute of Electrical Engineers*, New York City.
- Trans A I M E.** *Transactions of the American Institute of Mining Engineers*, New York.
- Trans A S C E.** *Transactions of the American Society of Civil Engineers*, New York; monthly.
- Trans A S M E.** *Transactions of the American Society of Mechanical Engineers*, New York
- Trans Can Soc C E.** *Transactions of the Canadian Society of Civil Engineers*, Montreal.
- Trans N A & M E.** *Transactions of the Society of Naval Architects and Marine Engineers*, Washington, D. C.; annual.
- Ztsch Oest.** *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins*; weekly.
- Ztsch Ver Ing.** *Zeitschrift des Vereins Deutscher Ingenieure*, Berlin, Germany; weekly.

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ALTERNATING CURRENT CURVES.

How to delineate alternating current curves when the alternator is inaccessible. By J. A. Flemming. —Elec. Engr., March, 1895.

ARCHITECTURE in France.

Characteristic features of recent structures. Their influence on American designs. Profusely illustrated. By Barr Ferree. —Eng. Mag., March, 1895.

BALL BEARINGS, Rolling Machine for —.

With illustrations of applicator of ball bearings to wagon and car axles. —Lon. Engineer, March 1, 1895.

BEACON Tower, Concrete —.

On the Plateau of Horaine off the coast of France. Plans and methods used in construction on this exceptionally exposed reef. Illustrated. —Sci. Am. Sup., March 9, 1895.

BELT, Quarter-Turn —.

Methods of turning power round a corner by belting. By D. N. Ricker. Illustrated. —Power, March, 1895.

BOILER Making.

Present practice in punching, planing, flanging, shearing, riveting, flue-setting and all the various processes. Extensive illustrations of machinery used. By William O. Webber. —Cassier, March, 1895.

BOILERS, Locomotive —.

Their power and efficiency, with especial attention to the question of grate areas. —R. R. Gaz., March 29, 1895.

BRIDGE, King Charles — at Stuttgart.

An article by Leibbrand describing this new highway bridge, especially the interesting problems encountered in getting the foundation for the piers. Well illustrated. —Ztsch Ver Ing., Feb. 9, 1895.

BRIDGE, Lift —.

The Halsted street bridge, Chicago. History, general and detailed description of the trussed span, towers and lifting machinery of this novel bridge. By J. A. L. Waddell. Fully illustrated. Extended discussion and correspondence. —Trans. A. S. C. E., Jan., 1895.

BRIDGE, North River —.

General specifications for the proposed 3100 ft. span suspension bridge at New York City. Loads, allowed unit strains, materials, details of construction and general items. —Eng. News, March 7, 1895. R. R. Gaz., March 8, 1895. Eng. Rec., March 16, 1895.

BRIDGE; Sixteenth St., Lift, —. Milwaukee, Wis.

Novel designs of this new bridge. Main girders carrying floor are horizontal and supported by a swinging strut near one end and by rollers near the other end. These girders and the strut lift to open the bridge, the centre of gravity moving horizontally. Illustrated. By John Geist. —Eng. News, March 7, 1895. Eng. Rec., March 9, 1895.

CABLE RAILWAY TUNNEL.

Construction of the Twenty-first street tunnel or conduit of the Chicago City Railway Co. Illustrated. —St. Ry. Jour., March, 1895.

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CABLE RAILWAY in Washington, D. C.

Car and power houses, track construction, underground work and rolling stock of the Columbia Railway Co. Illustrated.—St. Ry. Rev., March, 1895.

CANAL, North Sea and Baltic —.

Well illustrated.—Deutsche Bztg., March 2, 1895, et seq.

CANAL BOAT Haulage.

The Lamb electric cable-way for— Illustrated.—Elec. Engr., March 13, 1895.

CAST IRON Tests of.

See TESTS.

COAL Consumption.

Tabulated results from 24 electric lighting stations showing the fuel economy obtained. Results carefully compiled for National Electric Light Ass'n.—Eng. Rec., March 2, 1895. Eng. News, March 14, 1895. Elec. World, March 2, 1895.

CONCRETE Beacon Tower.

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CORROSION of Metals Under Stress.

Results of tests by Thomas Andrews indicate that the effect of stresses is to lessen corrosive action.—Eng. Rec., March 16, 1895.

CRANES Locomotive —.

Their characteristics, advantages, details of construction and use. Examples and illustrations of different current types. Wm. L. Clements.—Cassier, March, 1895.

CRUSHER, Portable Rock —.

Description of the Buchanan crusher, giving its advantages. Illustrated.—Eng. News, March 7, 1895.

CRYSTALLIZATION of Steel.

Explanation of fracture as due to crystallization urged to be a mistake. Editorial discussion.—R. R. Gaz., March 15, 1895.

DANUBE. Regulation of the —.

Paper by H. Arnold read before the Society of German Engineers at Berlin. A thorough description of this interesting work. Well illustrated.—Ztsch Ver Ing., Feb. 2, 1895, et seq.

DRAINING of the Haarlem Meer, Holland.

History and description of this work and of the pumping plant. Illustrated.—Lon. Eng., March 8, 1895.

DYNAMO, Automatic —.

Improved Ball Automatic Dynamo. Illustrated.—Elec. Engr., March 27, 1895.

DYNAMOS, Method of Preventing Armature Re-action.

By H. J. Ryan and M. E. Thompson. Abstract of paper read before the American Institute of Electrical Engineers. Illustrated.—Elec. Engr., March 27, 1895.

ELECTRIC ANNEALING.

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ELECTRIC CANAL STATION of St. Petersburg.

Descriptive article by A. G. Besson, giving the commercial and technical results of the running of this plant.—Ztsch Ver. Ing., Feb. 23, 1895.

ELECTRIC DISTRIBUTION by Monoclinic System.

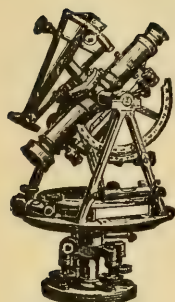
Abstract of paper read by Dr. Louis Bell at the Cleveland Convention of the National Electric Light Association.—Elec. Engr., March, 1895.

ELECTRIC ENERGY, Per Pound of Coal.

Report of the committee of the National Electric Light Association on the number of watts produced per pound of coal by various kinds of equipments in different plants.—Elec. Engr., Feb. 27, 1895.

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ELECTRIC ENERGY, Storage of —.

Essential to economy of working stations. Reasons and results. By Nelson W. Perry. —Elec. World, March 2, 1895.

ELECTRIC FIRE ALARM and Police System.

The Walter combination. Illustrated. —Elec. Engr., March 27, 1895.

ELECTRIC HEATERS

London Theatre. Illustrated. —Elec. Engr., March 27, 1895.

ELECTRIC LIGHT Carbons.

Effect of different carbons on the candle power of arc lamps. Paper read by L. B. Marks at the Cleveland convention of the National Electric Light Association. —Elec. Engr., Feb. 27, 1895.

ELECTRIC LIGHT PLANT.

Logansport, Ind., operated by a combination of steam and water power. Illustrated. —Elec. Engr., March 27, 1895.

ELECTRIC LIGHT AND RAILWAY PLANT.

The Electric Storage Battery Co.'s plant at Merrill, Wis. Illustrated. —Elec. Engr., March 13, 1895.

ELECTRIC LIGHT Tower.

Novel design of — in Bilboa and Chicago. Illustrated. —Elec. Engr., March 6, 1895.

ELECTRIC LIGHTING Engines.

The Siemens and Halske installation at Vienna, Austria. Interesting description, well illustrated, of engines especially designed to reduce all troubles arising from vibration. —Lon, Eng., Feb. 22, 1895.

ELECTRIC LIGHTING Statistics.

By I. C. Wood. —Elec. Engr., March 20, 1895.

ELECTRIC LOCOMOTIVES vs. Steam Locomotives.

By Wm. Baxter, Jr. —Elec. Engr., March 20, 1895.

ELECTRIC Mining.

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ELECTRIC MONOCLINIC SYSTEM.

Discussion by Dr. Louis Bell. —Elec. Engr., March 13, 1895.

ELECTRIC MOTOR.

New — brought out by the Triumph Electric Co. Illustrated. —Power, March, 1895.

ELECTRIC MOTOR for Machine Tools.

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ELECTRIC POWER, Industrial Use of —.

At Los Angeles, Cal. By G. H. Guy. Illustrated. —Elec. Engr., March 13, 1895.

ELECTRIC POWER Station.

Construction of a novel — at Columbus, O., in which the central dome has been utilized for the smokestack by means of forced draft. —St. Ry. Jour., March, 1895.

ELECTRIC POWER STATION.

For the Metropolitan Street Railway Co., New York. Illustrated. —St. Ry. Jour., March, 1895.

ELECTRIC POWER STATION, Fuel Consumption in —.

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ELECTRIC POWER Station.

The North Chicago and Chicago Electric Transit Co. Illustrated. —St. Ry. Jour., March, 1895.

ELECTRIC PROPELLOR.

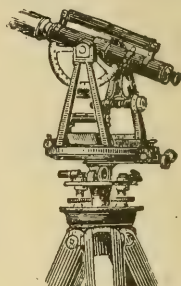
Boats, made by the Electric Boat Co. Illustrated. —Elec. Engr., March 20, 1895.

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ELECTRIC RAILWAY System.

At Lyons, France. Illustrated.—St. Ry. Jour., March, 1895.

ELECTRIC RAILWAY.

The Beecher Single Rail System. Illustrated.—Elec. Engr., March 13, 1895.

ELECTRIC RAILWAY.

cars.—St. Ry. Jour., March, 1895.

ELECTRIC RAILWAY of Bristol, England.

The new installation, with map of route and sketch of rail sections.—Lon. Engineer, March 8, 1895.

ELECTRIC RAILWAY Power Plant.

The installation at Allentown, Pa. Illustrated.—St. Ry. Gaz., March 30, 1895.

ELECTRIC RAILWAY Power Station.

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The street railway system of Buffalo, with illustrations of power house and

ELECTRIC RAILWAY, Rail Bond for —.

A perfect bond using a plastic compound which has stood a test of four years without increase of drop, and will carry 1500 amperes. By Harold P. Brown.—St. Ry. Rev., March, 1895. St. Ry. Gaz., March 23, 1895.

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Effect of — on electrolytic action.—Elec. Engr., March 20, 1895.

ELECTRIC RAILWAY Terminals.

At the Market street ferry, San Francisco, Cal. Illustrated.—St. Ry. Jour., March, 1895.

ELECTRIC RAILWAY, Underground, —, Buda Pesth.

General details of tunnel and its construction, track, motors and cars. Illustrated.—Eng. News, March 21, 1895. Eng. Rec., March 30, 1895.

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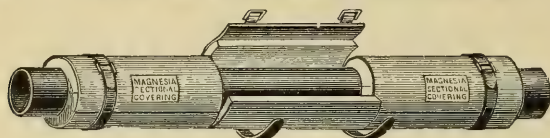
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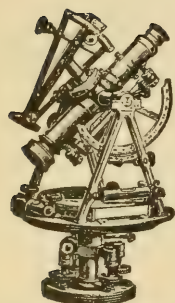
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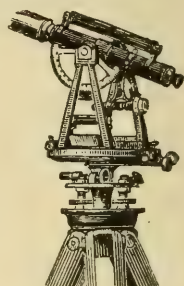
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Considerations of different modes of dealing with the trouble under differing conditions with diagrams. Maurice Hoopes.—Elec. World, May 25, 1895, p. 603.

ELECTRO-THERMAL WIRE vs. Electro Magnet,

By E. R. Knowles, E. E.—Elec. Engr., May 22, 1895, p. 458.

ELEVATED RAILWAY, Electric —.

The Metropolitan West Side Railway of Chicago. Said to be the finest elevated road in the world, and furnishing the widest application of electricity. Full description of elevated structure, electric plant and equipment. Profusely illustrated.—St. Ry. Rev., May, 1895, pp. 263-274; Elec. Eng., May 15, 1895, p. 433 et seq.

EMERY WHEELS and Tests.

Their manufacture, use, perfection and tests. T. Dunkin Paret.—Cassier, May, 1895, p. 50.

ENGINE for Electric Central Station Work.

The recent development of the single-acting high-speed engine. Mark Robinson. Serial.—Elec. Rev., May 17, 1895, p. 626.

ENGINE, Tests of a Regenerator Hot-Air —.

The tests were made by G. W. Bissell to determine the effect of varying the weight of the regenerator.—Trans. A. S. M. E., Vol. XV. (1894), p. 744.

ENGINES, Cylinder Proportions of Compound —.

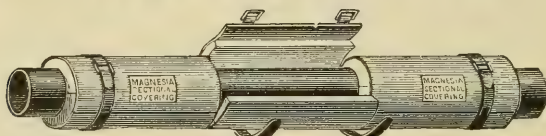
A method of proportioning the cylinders of compound engines by their free expansion losses, by Frank H. Ball.—Trans. A. S. M. E., Vol. XV. (1894), p. 759.

ENGINES, Heat —.

The development of their experimental study, showing that scientific advance and practical improvement proceeded together. The "James Forrest" lecture of the Institution of Civil Engineers, by Prof. W. C. Unwin.—Lon. Eng., May 3, 1895, p. 590, et seq; Lon. Engineer, May 3, 1895, p. 379, et seq; Eng. Rec., June 1, 1895, p. 9, et seq.



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INDEX TO CURRENT LITERATURE.

In this department is given an Index of current periodical engineering literature. To each title is appended a short note indicating the character of the article indexed. The index notes are printed on but one side of the paper, so that the titles may be cut out and pasted upon cards or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

All readers of the JOURNAL are requested to aid in making this Index as complete as possible. Notices for this department, and all matter to be indexed, should be sent to J. B. JOHNSON, Manager of Index Department, Washington University, St. Louis, Mo.

LIST OF PERIODICALS INDEXED.

Following the title of each periodical is given, in italics, the abbreviation by which it is referred to in the Index.

For alphabetical list of abbreviated titles, see page vii.

UNITED STATES.

ANNUAL.

- American Institute of Mining Engineers, Transactions of the** — (*Trans. A. I. M. E.*), 13 Burling Slip, New York; per year, \$5.
American Society of Mechanical Engineers, Transactions of the — (*Trans. A. S. M. E.*), 12 West Thirty-first Street, New York.
American Water Works Association, Proceedings of Annual Meetings of the — (*Am. W. W. Ass'n.*), 95 William Street, New York; per year, \$1.
Society of Naval Architects and Marine Engineers, Transactions of the — (*Trans. N. A. & M. E.*), W. L. Capps, Secretary, 1710 F Street N. W., Washington, D. C.; \$10 per annual volume.

QUARTERLY.

- Engineers' Club of Philadelphia, Proceedings of the** — (*Proc. Eng. Club Phila.*), 1122 Girard Street, Philadelphia, Pa.; per year, \$2.
New England Water Work Association, Journal of the — (*Jour. N. E. W. W. Assn.*), New London, Conn.; per year, \$2; single copies, 75 cents.
School of Mines Quarterly (*Sch. Mines Quart.*), Columbia College, New York City; per year, \$2; single copy, 50 cents.
Technology Quarterly and Proceedings of the Society of Arts (*Tech. Quart.*), Massachusetts Institute of Technology, Boston, Mass.; per year, \$3.
United States Naval Institute, Proceedings of the — (*Proc. U. S. N. I.*), United States Naval Institute, Annapolis, Md.; per year, \$3.50; single copy, \$1.

MONTHLY.

SOCIETIES.

- American Institute of Electrical Engineers, Transactions of the** — (*Trans. A. I. E. E.*), 12 West Thirty-first Street, New York City.
American Society of Civil Engineers, Transactions of the — (*Trans. A. S. C. E.*), 127 East Twenty-third Street, New York; per year, \$10.
Association of Engineering Societies, Journal of the — (*Jour. Assn. Eng. Socs.*), Philadelphia; per year, \$3; single copy, 30 cents.
Engineers' Society of Western Pennsylvania, Proceedings of — (*Proc. Eng. Soc. W. Pa.*), Allegheny, Pa.; per year, \$7; single copy, 75 cents.
Franklin Institute, Journal of the — (*Jour. Frank. Inst.*), Franklin Institute, Philadelphia, Pa.; per year, \$5; single copy, 50 cents.

Continued on page iii

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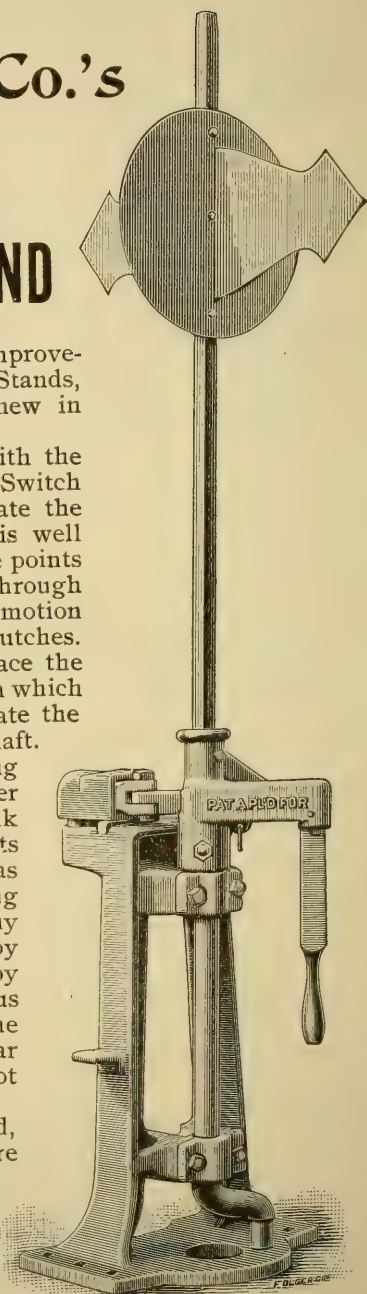
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MONTHLY—Continued.

PERIODICALS.

- Technical Society of the Pacific Coast, Transactions of the —** (*Trans. Tech. Soc. Pac. C.*), Rooms 56–57, 819 Market Street, San Francisco, Cal.
- American Engineer and Railroad Journal** (*Am. Eng. & R. R. Jour.*), 47 Cedar Street, New York; per year, \$3; single copy, 25 cents.
- Cassier's Magazine** (*Cassier*), World Building, New York; per year, \$3; single copy, 25 cents.
- Engineering Magazine** (*Eng. Mag.*), 47 Times Building, New York; per year, \$3; single copy, 25 cents.
- Engineering Mechanics** (*Eng. Mech.*), 430 Walnut Street, Philadelphia, Pa.; per year, \$1; single copy, 10 cents.
- Inland Architect and News Record** (*Inland Arch.*), The Inland Publishing Co., 19 Tribune Building, Chicago; per year, \$5; single copy, 50 cents; Photogravure Edition, per year, \$10; single copy, \$1.
- Irrigation Age** (*Irrigation Age*), Chicago, Ill.; per year, \$2.
- Master Steam Fitter** (*Mst. Stm. Fitter*), 218 La Salle Street, Chicago, Ill.; per year, \$1; single copy, 10 cents.
- Paving and Municipal Engineering** (*Par. & Munic. Eng.*), Municipal Engineering Co., 44 Chamber of Commerce, Indianapolis, Ind.; per year, \$2; single copy, 25 cents.
- Power** (*Power*), World Building, New York; per year, \$1; single copy, 10 cents.
- Railway Engineering and Mechanics** (*Ry. E. & M.*), 816 The Rookery, Chicago, Ill.; per year, \$1; single copy, 10 cents.
- Safety Valve** (*Sy. Valve*), 55 Liberty Street, New York; per year, \$1; single copy, 10 cents.
- Street Railway Journal** (*St. Ry. Jour.*), World Building, New York; per year, \$4; single copy, 35 cents.
- Stone** (*Stone*), Chicago; per year, \$2; single copy, 25 cents.
- Street Railway Review** (*St. Ry. Rev.*), 269 Dearborn Street, Chicago, Ill.; per year, \$2; single copy, 25 cents.

WEEKLY.

- American Architect** (*Am. Arch.*), Ticknor & Co., 211 Tremont Street, Boston, Mass.; single copy, 15 cents.
- American Machinist** (*Am. Mach.*), 96 Fulton Street, New York; per year, \$2; single copy, 10 cents.
- Boston Journal of Commerce** (*Bos. Jour. Com.*), 128 Purchase Street, Boston, Mass.; per year, \$3; single copy, 6 cents.
- Electrical Engineer** (*Elec. Engr.*), 203 Broadway, New York; per year, \$3.
- Electrical World** (*Elec. World*), 177 Times Building, New York; per year, \$3; single copy, 10 cents.
- Engineering and Mining Journal** (*E. & M. Journal*), 27 Park Place, New York; per year, \$5; single copy, 15 cents.
- Engineering News** (*Eng. News*), Tribune Building, New York; per year, \$5; single copy, 15 cents.
- Engineering Record** (*Eng. Rec.*), 277 Pearl Street, New York; per year, \$5; single copy, 12 cents.
- Railroad Gazette** (*R. R. Gaz.*), 73 Broadway, New York; per year, \$4.20; single copy, 10 cents.
- Scientific American Supplement** (*Sci. Am. Sup.*), 361 Broadway, New York; per year, \$5; single copy, 10 cents.
- Street Railway Gazette** (*St. Ry. Gaz.*), Monadnock Block, Chicago; per year, \$3; single copy, 25 cents.

CANADA.

- Canadian Society of Civil Engineers, Transactions of the —** (*Trans. Can. Soc. C. E.*), McGill University, Montreal.

GREAT BRITAIN.

- Electrical Review** (*Elec. Rev.*), 22 Paternoster Row, London, E. C.; weekly; per year, 21s, 8d; single copy, 4d.
- Engineer, The —** (*Lon. Engineer*), London, England; weekly; per year, \$10; single copy, 25 cents.
- Engineering** (*Lon. Eng.*), London, England; weekly; per year, \$10; single copy, 25 cents.
- Engineering Review** (*Eng. Rev.*), 29 Great George Street, S. W., England; monthly; single copy, 6d.
- Institution of Civil Engineers, Proceedings of the —** (*Proc. Inst. C. E.*), 25 Great George Street, Westminster, S. W., London, England.

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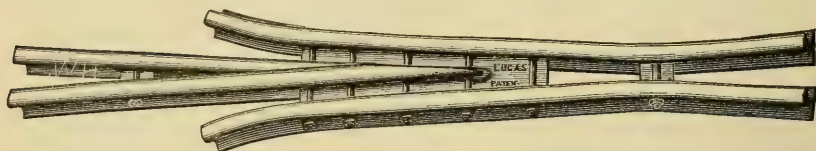
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List of Periodicals Indexed—Concluded.

WEEKLY.—Concluded.

- Institution of Mechanical Engineers, Proceedings of the** — (*Proc. Inst. Mech. Engrs.*), 19 Victoria Street, Westminster, S. W., London, England.
Mechanical World (*Mech. World*), Manchester, England; weekly; per year, 8s, 8d.
Practical Engineer (*Prac. Engr.*), 2 Amen Corner, London, E. C., England; weekly; per year, 10s.
Railway Engineer (*Ry. Eng.*), 8 Catherine Street, Strand, W. C., London, England; monthly; single copy, 1s.

INDIA.

- Indian Engineer** (*Ind. Engr.*), Calcutta, India; per year, 20 Rs.
Indian Engineering (*Ind. Engng.*), Calcutta, India, weekly; per year, 18s; single copy, 8 annas.

FRANCE.

- Ponts et Chaussées, Annales des** — (*Annales des P. & C.*), monthly, Vve. Ch. Dunod, 49 Quai des Augustins, Paris, France.
Société des Ingénieurs Civils, Mémoires de la — (*Méms. Soc. Ing. Civils*), monthly, 10 Cité Rougement, Paris.

GERMANY, AUSTRIA AND SWITZERLAND.

- Archiv für Eisenbahnwesen** (*Arch. f. Eisenbw.*), bi-monthly, Julius Springer, Berlin, Germany; per year, 12 marks.
Civilingenieur, Der — (*Oiv. Ing.*), monthly.
Deutsche Bauzeitung (*Deutsche Bztg.*), semi-weekly, Berlin, Germany; per year, 12 marks.
Journal für Gasbeleuchtung und Wasserversorgung (*Jour. f. Gasb. u. Wasserv.*), three times a month, 11 Glückstrasse, Munich, Germany; per year, 20 marks.
Praktische Maschinen-Constructeur, Der—(*Pr. Msch. Cnstr.*), bi-weekly, Leipzig-Gohlis, Germany; per year, 16 marks.
Schweizerische Bauzeitung (*Schw. Bztg.*), German and French, 32 Brandschenkestrasse, Zurich
Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins (*Ztsch. Oestl.*), weekly.
Zeitschrift des Vereines Deutscher Ingenieure (*Ztsch. Ver. Ing.*), weekly, Berlin, Germany; per year, 32 marks.

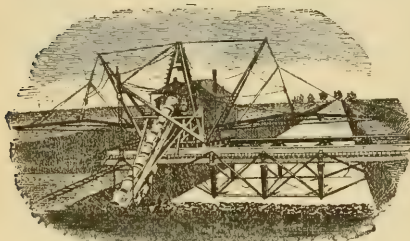
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For list of full titles, see page i.

- Am Arch.** *American Architect*, Boston; weekly.
- Am Eng & R R Jour.** *American Engineer & Railroad Journal*, New York; monthly.
- Am Mach.** *American Machinist*, New York; weekly.
- Am. W. W. Assn.** *Proceedings, American Water Works Association*, New York; annual.
- Annales des P & C.** *Annales des Ponts et Chaussées*, Paris, France; monthly.
- Arch f Eisenbw.** *Archiv für Eisenbahnwesen*, Berlin, Germany; bi-monthly.
- Bos. Jour. Com.** *Boston Journal of Commerce*, Boston, Mass.; weekly.
- Cassier.** *Cassier's Magazine*, New York; monthly.
- Civ Ing.** *Der Civilingenieur*; monthly.
- Deutsche Bztg.** *Deutsche Bauzeitung*, Berlin, Germany; semi-weekly.
- E & M Journal.** *Engineering and Mining Journal*, New York; weekly.
- Elec Eng.** *The Electrical Engineer*, New York; weekly.
- Elec Rev.** *Electrical Review*, London, Eng.; weekly.
- Elec World.** *The Electrical World*, New York; weekly.
- Eng Mag.** *The Engineering Magazine*, New York; monthly.
- Eng Mech.** *Engineering Mechanics*, Philadelphia, Pa.; monthly.
- Eng News.** *Engineering News*, New York; weekly.
- Eng Rec.** *Engineering Record*, New York; weekly.
- Eng Rev.** *Engineering Review*, London, Eng.; monthly.
- Ind Engng.** *Indian Engineering*, Calcutta, India; weekly.
- Ind. Engr.** *Indian Engineer*, Calcutta, India; weekly.
- Inland Arch.** *The Inland Architect and News Record*, Chicago, Ill.; monthly.
- Irrigation Age.** *The Irrigation Age*, Chicago, Ill.; monthly.
- Jour Assn Eng Socs.** *Journal of the Association of Engineering Societies*, Philadelphia; monthly.
- Jour f Gasb u Wasserv.** *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Germany; three times a month.
- Jour Frank Inst.** *Journal of the Franklin Institute*, Philadelphia, Pa.; monthly.
- Jour NEW W Assn.** *Journal of the New England Water Work Association*, New London, Conn.; quarterly.
- Lon Eng.** *Engineering*, London, England; weekly.
- Lon Engineer.** *The Engineer*, London, England; weekly.
- Mst. Stm. Fitter.** *Master Steam Fitter*, Chicago, Ill.; monthly.
- Mech World.** *The Mechanical World*, Manchester, England; weekly.
- Mems Soc Ing Civ.** *Mémoires de la Société des Ingénieurs Civils*, Paris; monthly.
- Pav & Munic Eng.** *Paving and Municipal Engineering*, Indianapolis, Ind.; monthly.
- Power.** *Power*, New York; monthly.
- Pr Msch Cnstr.** *Der Praktische Maschinen-Constructeur*, Leipsic.
- Prac. Engr.** *Practical Engineer*, London; weekly.
- Proc Eng Club Phila.** *Proceedings of the Engineers' Club of Philadelphia*, Philadelphia, Pa.; quarterly.
- Proc Eng Soc W Pa.** *Proceedings of Engineers' Society of Western Pennsylvania*, Pittsburg, Pa.; monthly.
- Proc Inst C E.** *Proceedings of the Institution of Civil Engineers*, London, England
- Proc Inst Mech Engrs.** *Proceedings of the Institution of Mechanical Engineers*, London, England.
- Proc U S N I.** *Proceedings of the United States Naval Institute*, Annapolis, Md.; quarterly.
- R R Gaz.** *Railroad Gazette*, New York; weekly.
- Ry E & M.** *Railway Engineering and Mechanics*, Chicago, Ill.; monthly.
- Ry Eng.** *The Railway Engineer*, London, England; monthly.
- Sch Mines Quart.** *School of Mines Quarterly*, New York City.
- Schw Bztg.** *Schweizerische Bauzeitung*, Zurich; German and French; weekly.
- Sci Am Sup.** *Scientific American Supplement*, New York; weekly.
- Stone.** *Stone*, Chicago, Ill.; monthly.
- St Ry Gaz.** *The Street Railway Gazette*, Chicago, Ill.; weekly
- St Ry Jour.** *Street Railway Journal*, New York; monthly.
- St Ry Rev.** *Street Railway Review*, Chicago, Ill.; monthly.
- Sy Valve.** *Safety Valve*, New York; monthly.
- Tech Quart.** *Technology Quarterly and Proceedings of the Society of Arts*, Boston, Mass
- Trans A I E E.** *Transactions of the American Institute of Electrical Engineers*, New York City.
- Trans A I M E.** *Transactions of the American Institute of Mining Engineers*, New York.
- Trans A S C E.** *Transactions of the American Society of Civil Engineers*, New York; monthly.
- Trans A S M E.** *Transactions of the American Society of Mechanical Engineers*, New York
- Trans Can Soc C E.** *Transactions of the Canadian Society of Civil Engineers*, Montreal.
- Trans N A & M E.** *Transactions of the Society of Naval Architects and Marine Engineers*, Washington, D. C.; annual.
- Trans Tech Soc Pac C.** *Transactions of the Technical Society of the Pacific Coast*, San Francisco, Cal.
- Ztsch Oest.** *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins*; weekly.
- Ztsch Ver Ing.** *Zeitschrift des Vereins Deutscher Ingenieure*, Berlin, Germany; weekly.

For list of full titles, see page i.

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INDEX.

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- AIR. Compressed —. Dredging by means of —. See Dredging.
- AIR. Compressed—. Piping for—. Diameter of—. By Frank Richards, *Am. Mach.*, Dec. 27, 1894.
- AIR. Compressed—, as used in the shops of the Delaware, Lackawanna and Western Railroad, at Buffalo. Illustrated. *F. M. Wilder. R. R. Gaz.* Jan. 4, 1895.
- AIR PUMP. Capacity of —, with hints in designing. By Charles M. Jones. *Am. Mach.*, Jan. 10, 1895.
- AMBULANCE. Street Railway —. See Street Railway.
- ARCHITECTURE of Municipal Buildings. Materials and style as affected by their purpose, situation and use. Illustrated extensively from American and foreign cities. *E. C. Gardner. Eng. Mag.*, Jan., 1895.
- ARCHITECTURE. The new City Hall of Gelsenkirchen. Article by E. Endler, the architect of the building. It is accompanied by excellent illustrations. *Deutsche Bztg.*, Jan. 5, 1895.
- ARCHITECTURE of the University of Virginia. The influence of Thomas Jefferson on plans and details. *Am. Arch.*, Jan. 19, 1895.
- ASPHALT PAVING. The practice of twelve different cities concerning base, binder, cost and general details. *Eng. News*, Jan. 10, 1895.
- BATTERY. Storage —. The Hess —. Illustrated. *Elec. Eng.*, Dec. 12, 1894.
- BATTERY. Storage—. Historical review, and an account of many of the present batteries and of their action and parts. Illustrated. *J. Appleton. Elec. World*, Jan. 5, 1895.
- BATTERY. Storage— for lighting and street railway, Merrill, Wis. *G. Herbert Condict. Elec. World*, Jan. 26, 1895. *St. Ry. Gaz.*, Jan. 26, 1895.
- BATTERY. Storage—. The Syracuse Storage Battery for traction, central stations and private use. Illustrated. *Elec. Eng.*, Dec. 5, 1894.
- BELT SHIFTERS. Electric. Illustrated description of automatic electric belt shifters. By H. V. Parsall, Jr. *Elec. Eng.*, Dec. 12, 1894.
- BELTING. Cements for joints in —. Compositions of —. *Power*. Dec., 1894.
- BELTING. Width of—, for any required horse power. By J. L. Bixby. *Power*, Dec., 1894.
- BOILERS. Explosions of —. Their causes, with especial consideration of the Shamokin disaster. *John L. Gill, Jr. Proc. Eng. Club, Phila.*, Jan., 1895.
- BOILERS. Explosion of — in France. Statistics of —. Article by Prof. R. C. Carpenter. *Safety Valve*, Dec. 15, 1894.
- BOILERS. Explosions in Kitchen—. Experiments showing that explosions are caused by a closing of outlets, the safety valve being a perfect safeguard. Boilers heated red hot and then filled with water do not explode. *Am. Arch.*, Jan. 26, 1895.
- BOILERS. Locomotive—. Efficiency of—. Tests by George Marie, in France, showing influence of arches in firebox, length of tubes and blast on combustion, on efficiency of boiler and on temperature of the smokebox. Illustrated abstract of valuable investigations. *R. R. Gaz.*, Jan. 25, 1895.
- BOILERS. Locomotive—. Steel for fireboxes and boiler shells, with tests, forms and sizes of tubes and their effects, incrustation and system of boiler feed-

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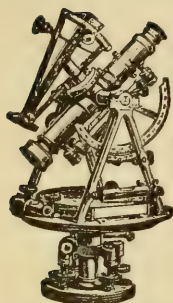
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- ing and smokebox arrangement, and its effect in European locomotives. Abstract of Bulletin of International Railroad Congress Commission. R. R. Gaz., Jan. 11, 1895.
- BOILERS. Losses in — and their causes. Abstract of paper read by D. Ashworth before Am. Soc. of M. E. Safety Valve, Dec. 15, 1894.
- BRAKES. For testing the efficiency of motors; and the various arrangements in use for measuring the power of motors. An interesting and very instructive article. Illustrated. Pr. Msch. Cnstr., Jan. 3, 1895, et seq.
- BRIDGE. Floating —, across the Dina at Riga. A well illustrated article by A. Agthe, describing a very peculiar form of bridge necessitated by the condition of the river to be crossed. Ztsch. Ver. Ing., Jan. 12, 1895.
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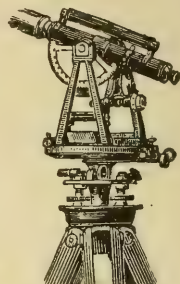
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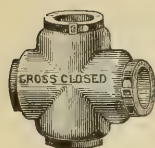
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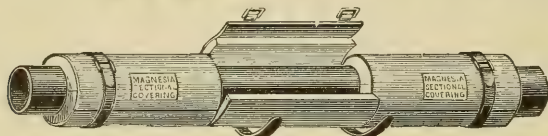
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- PHOTOGRAPHS.** Electric Transmission of—. Transmitting, recording and seeing pictures by electricity, by George R. Carey. Illustrated. Elec. Eng., Jan. 16, 1895.
- PIPE.** Covering for Steam—Experiments on—by Louis Schmidt. Power, Dec., 1894.
- PLANIMETER.** A New—, that will indicate, without computation, the horse power shown on the diagram. Power, Dec., 1894.
- PLOWS.** Electric—. Recent experiments in Germany. Illustrated. Elec. Engr., Dec. 26, 1894.
- POWER.** Measurement of—. Brakes and dynamometers theoretically and practically considered. Valuable general article, describing different forms and their special applicability. Fully illustrated. G. D. Hiscox. Sci. Am. Sup., Jan. 5, 1895.
- PULLEY.** Split—, the Dryden. Illustrated. Am. Mach., Dec. 13, 1894.
- PUMP.** Air—. See Air Pump.
- PUMP and Compressor.** Guild & Garrison's improved vacuum pump and compressor. Illustrated. Am. Mach., Jan. 3, 1895.
- PUMP.** Power—. Gould Mfg. Co.'s new triplex power pump for high pressure. Illustrated. Am. Mach., Jan., 24, 1895.
- PUMP.** Steam—. Mason direct-acting steam pump. Illustrated. Am. Mach., Jan. 17, 1895.
- RAILROAD Crossings.** See Crossings.
- RAILROAD.** Proposed Underground. The latest plans of the Rapid Transit Commissioners of New York city, with objections to previous provisional plans. By William Barclay Parsons, chief engineer. Illustrated. R. R. Gaz., Jan. 4, 1895.
- RAILROAD Signalling.** A very comprehensive and valuable paper concerning the history of the different systems and details of those in present use; the automatic lock and block system, and special mention of the Sykes system. John P. O'Donnell. Lengthy discussion. Trans. A. S. C. E., Nov., 1894.
- RAILROAD.** The St. Gothard. The construction, management, extension and working of this important line. C. S. Du Riche Preller. Lon. Eng., Jan. 4, 1895, et seq.
- RAILROAD.** Transition Curves for—. See Transition Curves.
- RAILS.** Steel. Process of Manufacture of. Illustrated. St. Ry. Jour., Jan., 1895.
- RESERVOIR.** Iron. Recently constructed at Bordeaux, of 560,000 gallons capacity, with wrought iron sides and roof. Short illustrated description. Lon. Engineer, Jan. 11, 1895.
- SANITATION,** Improved Methods of House Drainage. Recent improvements discussed before the Architectural League. Wm. Paul Gerhard. Am. Arch., Jan. 5, 1895. Sci. Am. Sup., Jan., 26, 1895.
- SCREWS.** New Thread for—designed to replace square threads. By A. M. Powell. Illustrated. Am. Mach., Jan. 24, 1895.
- SCREW MACHINE.** Turret screw machine, with chasing bar, made by Alfred Herbert, of Coventry, England. Illustrated. Am. Mach., Jan. 17, 1895.
- SCREW THREAD.** Metrical—. The machinery and methods used by Ludwig Loewe & Co., in Berlin. Ztsch. Ver. Ing., Jan. 12, 1895.
- SEPARATOR.** Entrained Water—designed by John E. Sweet, and brought out by the Straight Line Engine Co. Illustrated. Am. Mach., Dec. 20, 1894.
- SEWAGE DISPOSAL** at Manchester, England. The sewers and the disposal works for treating chemically and filtering 2,400,000 cubic feet per day. Wm. Thomas Olive. Proc. Inst. Mech. Engs., July, 1894.
- SEWER PIPE JOINTS.** Tests of tightness of cement joints, with deductions as to composition of cement and its use and as to form of joint. Freeman C. Coffin. Jour. Assn. Eng. Soc., Dec., 1894. Eng. News, Jan. 3, and 10, 1895.
- SHAPING MACHINE.** See Machine.

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- SNOW PLOW.** Electric—for electric street railways. Illustrated. Elec. Eng., Jan. 2, 1895.
- SNOW PLOW.** Electric—for electric street railways of the Pennsylvania Traction Company, Lancaster, Pa. Illustrated. St. Ry. Jour., Jan., 1895.
- SNOW PLOW.** Electric. Hirt's patent electric steel snow plow, made by J. L. White Mfg. Co., New York. Illustrated. St. Ry. Jour., Jan., 1895.
- SNOW PLOW and Rail Scraper,** used on the Richmond City Railway Co. Illustrated. St. Ry. Jour., Jan., 1895.
- SNOW PLOW.** The Taunton—, made by the Taunton Locomotive Co. Illustrated. St. Ry. Jour., Jan., 1895.
- STEAM ENGINE.** Automatic—of new design, built by the Atlas Engine Works, and termed the Atlas Cycloidal Engine. Power, Jan., 1895.
- STEAM ENGINES.** Comparative efficiencies of—. Comparison of the action of a fixed cut-off and throttling regulation with that of the automatic variable cut-off and compound engines. Discussion presented to Am. Soc. of M. E. by Chas. T. Porter, together with the description of a new design of throttling engine, having a cam valve. Illustrated. Power, Jan., 1895. Safety Valve, Jan., 1895.
- STEAM ENGINES.** Condenser for steam. Illustration and description of a new condenser brought out by H. R. Worthington. Power, Dec., 1894.
- STEAM ENGINE.** Erection of Corliss—-. By A. S. Mann. Illustrated. Power, Dec. 1894, et seq.
- STEAM ENGINES.** Governing—-. Experiments on by means of compression. Paper read before the Am. Soc. of M. E. by Jno. H. Barr. Am. Mach., Jan. 24, 1895.
- STEAM ENGINES.** Horse Power of—Nominal. Article by A. Slucki, advocating the classification of engines according to nominal horse power, but giving new rules for this classification. Ztsch. Ver. Ing., Jan. 12, 1895.
- STEAM ENGINES.** Losses in—. Drop losses in multiple expansion engines. By Chas. M. Jones. Am. Mach., Dec. 20, 1894.
- STEAM ENGINES.** Safety devices for—. Various arrangements which have been tried in the last few years to prevent accidents causing loss of life, etc. The arrangements described and illustrated are all devices which will stop the engine in case of necessity. Ztsch. Ver. Ing., Dec. 22, 1894.
- STEAM ENGINE.** Test—. An article by Professor Schroeter, in Munich, describing a thorough trial of a steam engine, working with highly superheated steam, and of the boiler furnishing the steam. The results obtained make this article one of an extraordinary interest. The article is fully illustrated. Ztsch. Ver. Ing., Jan. 5, 1895.
- STEAM ENGINE.** Trial of a compound—having cylinder ratio of 7 to 1. Paper read by F. W. Dean before Am. Soc. Mech. Eng., describing the trial of. Safety Valve, Dec. 15, 1894.
- STEAM ENGINES.** Trial of a vertical triple expansion condensing pumping engine at the Trenton Water Works. Abstract of paper by S. W. and S. S. Webber, read before Am. Soc. of Mech. Eng. Safety Valve, Dec. 15, 1894.
- STEAM ENGINES,** with triangular connecting rod. Article describing and illustrating an engine which employs a triangular frame connecting rod to transmit the driving effort from a pair of crossheads to one crank pin. Am. Mach., Dec. 27, 1894.
- STEAM SHOVEL.** The—. Its design, manufacture, economy and adaptability. A strong and thorough article. Illustrated. A. W. Robinson. Cassier, Jan., 1895.
- STEEL and concrete in combination.** See Concrete.
- STEEL PIPE.** Specifications for riveted—for the water works system of Cambridge, Mass. L. M. Hastings, City Engineer. Eng. Rec., Jan. 5, 1895.
- STONE.** Bedford—. Its qualities and value as a building stone, methods of quarrying and general history. 60 pages, profusely illustrated. Stone, Jan., 1895.

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- STONE Crushing Plant.** The works for crushing, elevating, screening, storing and conveying stone, recently erected on the Palisades of New Jersey. Eng. Rec., Jan. 26, 1895.
- STREET CAR Running Gear.** Rigid and flexible wheel bases. Their claims discussed, and the special advantages of the maximum traction truck shown, with editorial comment. Eng. News, Jan. 24, 1895.
- STREET RAILWAY Ambulance,** as planned by Dr. George Homan, Health Commissioner, and in regular service on a St. Louis electric line. A complete illustrated description. St. Ry. Rec., Jan., 1895.
- STREET RAILWAY.** Gas Motor for—. The Luehrig—as used in Dresden and Dessau. Illustrated. Frederick A. Kummer. Eng. News, Jan. 24, 1895.
- SURVEYS.** Hydrographic—. The cost for eleven river and harbor surveys, with conditions affecting each, and apportionment of expenditures. Capt. Wm. M. Black. Eng. News, Jan. 10, 1895.
- SWITCHBOARD.** Electric—. Illustrated description of an economical series street-lighting switchboard. Elec. Engr., Dec. 26, 1894.
- SWITCHBOARD.** The Evolution of a—. History of the necessity and growth of the switchboard, its necessary capabilities and numerous forms, and lines of probable future development. Lecture at the University of Wisconsin by Arthur Vaughan Abbott. Bulletin, University of Wis., 1894, No. 4.
- TELEPHONE.** The Long Distance—. The gradual growth of the telephone; following advancing electrical research, and the battery transmitter, making possible the long distance telephone. F. W. Dunbar. Elec. World, Jan. 12, 1895.
- TELEPHONE,** A new wire core telephone brought out by Herr W. Ohnesorge, of Frankfort, Germany. Illustrated. Elec. Eng., Jan. 1, 1895.
- TELEPHONE.** The Switchboard—. See Switchboard.
- THEATRES.** Three papers as follows, by Wm. Paul Gerhard, C. E.:
1. The Essential Conditions of Safety in Theatres: An essay on modern theatre planning, construction, equipment, and management, Am. Arch., June 23, July 7, 14, 21, 1894.
 2. The Water Service and Fire Protection of Theatres. Paper prepared for annual meeting, June 14, 1895, of New England Water Works Association. Published in abstract in Jour. N. E. W. W. Asso., Dec., 1894. Published in full in Fire and Water, from Sept. 15, 1894, et seq.
 3. Theatre Fire Catastrophes and Their Prevention. Paper prepared for the annual meeting at Montreal, Aug. 8, 1894, of International Assn. of Fire Engrs. Printed in full in Annual Report of Proceedings of that Assoc. for 1894. Printed in full in Sci. Am. Sup., Oct 27 and Nov. 3, 1894. Printed in full in Fire and Water, from Nov. 17, 1894, et seq.
- TRACKLAYING by Machinery.** Accounts of the Holman, the Harris and the Roberts tracklaying machines, with railroads that have used them, and their records; with editorial comment. Eng. News, Jan. 3, 1895.
- TRAINS.** Resistance of—. Article by C. W. MacCord, comparing formulæ for train resistance, and applying same to the Empire State Express. Am. Mach., Dec. 20, 1894.
- TRANSITION CURVES.** Illustrations, tables and extensive discussion. Edwin E. Woodman. Jour. Assn. Eng. Soc., Dec., 1894.
- TUNNEL.** The Simplon—. Full and interesting account, giving alignment, profiles, water power installation, ventilation, contract and mode of construction of this double tunnel, 12¼ miles in length. Sci. Am. Sup., Jan. 12, 1895. Lon. Engineer, Jan. 4, 1895, et seq.
- TUNNEL.**—The Thames—at Blackwall. History of the movement, design and leading features of the work, and details and account of construction to date. External diameter of tunnel, 27 feet, lined with cast iron, driven forward by use of a shield. Lon. Eng., Jan. 4, 1895, et seq.
- TURBINES Driving Electric Railway Generators.** Their field of usefulness, the problem governing them, and its solution. Illustrated from practical experience by Mark A. Replogle. St. Ry. Rev., Jan., 1895.

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- UNITS OF MEASURE.** A Proposal for Absolute—. An exhaustive article by M. Grubler, based on the metrical system, but of interest to every engineer. who has felt the want of a thorough revision of the system of units of measure now in use. *Ztsch. Ver. Ing.*, Dec. 15, 1895.
- VALVES.** Automatic.—. Water pipe syphon valves designed to act in case of accident to the syphons. Details of their construction on the Thirlmere water supply for Manchester, England. Illustrated. *Eng. Rec.*, Jan. 19, 1895.
- WATER SUPPLY** of the City of Rome. A discussion of the II books of Frontinus on the water supply of the ancient city, and a study of the old aqueducts. Clemens Herschel. *Eng. Rec.*, Jan. 5, 1895, et seq.
- WATER SUPPLY.** Town—. A system of bore-hole wells advocated, four such wells being more economical and efficient than one large well. Advantages of operation and application of pumping machinery shown. Henry Davey. *Cassier*, Jan., 1895.
- WATER WORKS.** Pipe Valves. See Valves.
- WELDING.** Electric—. Description, with general discussion of the effectiveness of the weld. Benjamin Alfred Dobson. *Proc. Inst. Mech. Engs.*, July, 1894.
- WELLS** for Water Supply. See Water Supply.
- WHEEL FLANGES** for Street Railways. Illustrated. *St. Ry. Jour.*, Jan., 1895.
- WIND.** Velocity of—. The effect of high velocities on structures probably 40 per cent. less in fact than usual formulas indicate. Results of tests on Eiffel Tower by Mr. Koechlin. *Sci. Am. Sup.*, Jan. 5, 1895.
- WRECKS** and Strandings. Rules governing their regulation in France. Historical resume of laws, their results and applications, and suggested lines of future action. A very extended discussion on the subject in general. M. Chargue-rand. *Annales des P. & C.*, Nov., 1894.

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LIST OF PERIODICALS INDEXED.

Following the title of each periodical is given, in italics, the abbreviation by which it is referred to in the Index.

For alphabetical list of abbreviated titles, see page vii.

UNITED STATES.

ANNUAL.

- American Institute of Mining Engineers, Transactions of the** — (*Trans. A. I. M. E.*), 13 Burling Slip, New York; per year, \$5.
American Society of Mechanical Engineers, Transactions of the — (*Trans. A. S. M. E.*), 12 West Thirty-first Street, New York.
American Water Works Association, Proceedings of Annual Meetings of the — (*Am. W. W. Ass'n.*), 95 William Street, New York; per year, \$1.
Society of Naval Architects and Marine Engineers, Transactions of the — (*Trans. N. A. & M. E.*), W. L. Capps, Secretary, 1710 F Street N. W., Washington, D. C.; \$10 per annual volume.

QUARTERLY.

- Engineers' Club of Philadelphia, Proceedings of the** — (*Proc. Eng. Club Phila.*), 1122 Girard Street, Philadelphia, Pa.; per year, \$2.
New England Water Work Association, Journal of the — (*Jour. N. E. W. W. Assn.*), New London, Conn.; per year, \$2; single copies, 75 cents.
School of Mines Quarterly (*Sch. Mines Quart.*), Columbia College, New York City; per year, \$2; single copy, 50 cents.
Technology Quarterly and Proceedings of the Society of Arts (*Tech. Quart.*), Massachusetts Institute of Technology, Boston, Mass.; per year, \$3.
United States Naval Institute, Proceedings of the — (*Proc. U. S. N. I.*), United States Naval Institute, Annapolis, Md.; per year, \$3.50; single copy, \$1.

MONTHLY.

SOCIETIES.

- American Institute of Electrical Engineers, Transactions of the** — (*Trans. A. I. E. E.*), 12 West Thirty-first Street, New York City.
American Society of Civil Engineers, Transactions of the — (*Trans. A. S. C. E.*), 127 East Twenty-third Street, New York; per year, \$10.
Association of Engineering Societies, Journal of the — (*Jour. Assn. Eng. Socs.*), Philadelphia; per year \$3; single copy, 30 cents.
Engineers' Society of Western Pennsylvania, Proceedings of — (*Proc. Eng. Soc. W. Pa.*), Allegheny, Pa.; per year, \$7; single copy, 75 cents.
Franklin Institute, Journal of the — (*Jour. Frank. Inst.*), Franklin Institute, Philadelphia, Pa.; per year, \$5; single copy, 50 cents.

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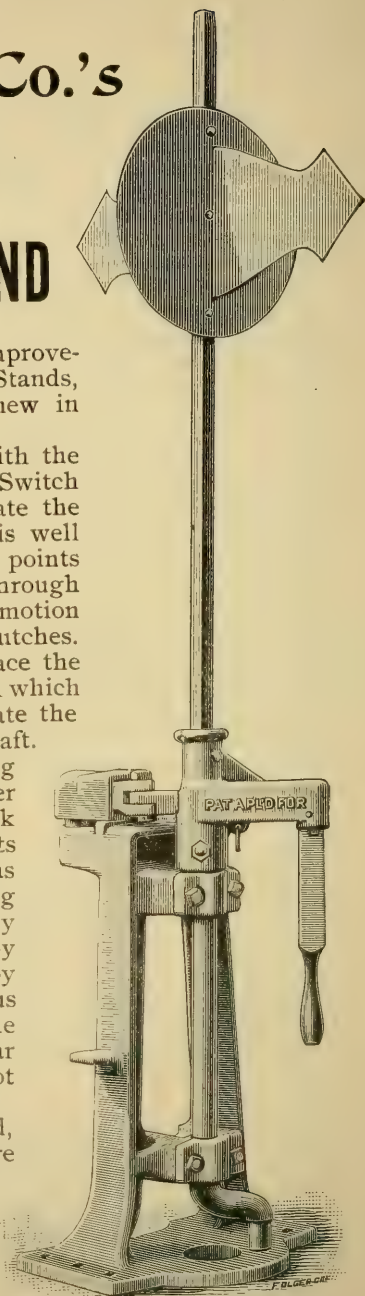
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- Technical Society of the Pacific Coast, Transactions of the** — (*Trans. Tech. Soc. Pac. C.*), Rooms 56-57, 819 Market Street, San Francisco, Cal.
- American Engineer and Railroad Journal** (*Am. Eng. & R. R. Jour.*), 47 Cedar Street, New York; per year, \$3; single copy, 25 cents.
- Cassier's Magazine** (*Cassier*), World Building, New York; per year, \$3; single copy, 25 cents.
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- Engineering Mechanics** (*Eng. Mech.*), 430 Walnut Street, Philadelphia, Pa.; per year, \$1; single copy, 10 cents.
- Inland Architect and News Record** (*Inland Arch.*), The Inland Publishing Co., 19 Tribune Building, Chicago; per year, \$5; single copy, 50 cents; Photogravure Edition, per year, \$10; single copy, \$1.
- Irrigation Age** (*Irrigation Age*), Chicago, Ill.; per year, \$2.
- Master Steam Fitter** (*Mst. Stm. Fitter*), 218 La Salle Street, Chicago, Ill.; per year, \$1; single copy, 10 cents.
- Paving and Municipal Engineering** (*Par. & Munic. Eng.*), Municipal Engineering Co., 44 Chamber of Commerce, Indianapolis, Ind.; per year, \$2; single copy, 25 cents.
- Power** (*Power*), World Building, New York; per year, \$1; single copy, 10 cents.
- Railway Engineering and Mechanics** (*Ry. E. & M.*), 816 The Rookery, Chicago, Ill.; per year, \$1; single copy, 10 cents.
- Safety Valve** (*Sy. Valve*), 55 Liberty Street, New York; per year, \$1; single copy, 10 cents.
- Street Railway Journal** (*St. Ry. Jour.*), World Building, New York; per year, \$4; single copy, 35 cents.
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- Engineering Record** (*Eng. Rec.*), 277 Pearl Street, New York; per year, \$5; single copy, 12 cents.
- Railroad Gazette** (*R. R. Gaz.*), 73 Broadway, New York; per year, \$4.20; single copy, 10 cents.
- Scientific American Supplement** (*Sci. Am. Sup.*), 361 Broadway, New York; per year, \$5; single copy, 10 cents.
- Street Railway Gazette** (*St. Ry. Gaz.*), Monadnock Block, Chicago; per year, \$3; single copy, 25 cents.

CANADA.

- Canadian Society of Civil Engineers, Transactions of the** — (*Trans. Can. Soc. C. E.*), McGill University, Montreal.

GREAT BRITAIN.

- Electrical Review** (*Elec. Rev.*), 22 Paternoster Row, London, E. C.; weekly; per year, 21s, 8d; single copy, 4d.
- Engineer, The** — (*Lon. Engineer*), London, England; weekly; per year, \$10; single copy, 25 cents.
- Engineering** (*Lon. Eng.*), London, England; weekly; per year, \$10; single copy, 25 cents.
- Engineering Review** (*Eng. Rev.*), 29 Great George Street, S. W., England; monthly; single copy, 6d.
- Institution of Civil Engineers, Proceedings of the** — (*Proc. Inst. C. E.*), 25 Great George Street, Westminster, S. W., London, England.

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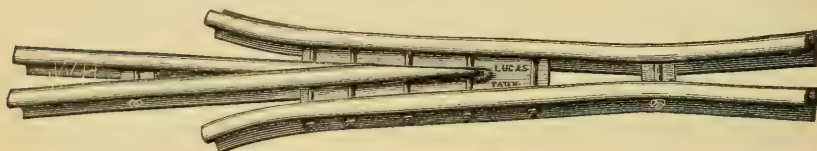
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WEEKLY.—Concluded.

- Institution of Mechanical Engineers, Proceedings of the** — (*Proc. Inst. Mech. Engrs.*), 19 Victoria Street, Westminster, S. W., London, England.
Mechanical World (*Mech. World*), Manchester, England; weekly; per year, 8s, 8d.
Practical Engineer (*Prac. Engr.*), 2 Amen Corner, London, E. C., England; weekly; per year 10s.
Railway Engineer (*Ry. Engr.*), 8 Catherine Street, Strand, W. C., London, England; monthly; single copy, 1s.

INDIA.

- Indian Engineer** (*Ind. Engr.*), Calcutta, India; per year, 20 Rs.
Indian Engineering (*Ind. Engng.*), Calcutta, India, weekly; per year, 18s; single copy, 8 annas.

FRANCE.

- Ponts et Chaussees, Annales des** — (*Annales des P. & C.*), monthly, Vve. Ch. Dunod, 49 Quai des Augustins, Paris, France.
Société des Ingénieurs Civils, Mémoires de la — (*Méms. Soc. Ing. Civils*), monthly, 10 Cité Rougemont, Paris.

GERMANY, AUSTRIA AND SWITZERLAND.

- Archiv für Eisenbahnwesen** (*Arch. f. Eisenbw.*), bi-monthly, Julius Springer, Berlin, Germany; per year, 12 marks.
Civilingenieur, Der — (*Civ. Ing.*), monthly.
Deutsche Bauzeitung (*Deutsche Bztg.*), semi-weekly, Berlin, Germany; per year, 12 marks.
Journal für Gasbeleuchtung und Wasserversorgung (*Jour. f. Gasb. u. Wasserv.*), three times a month, 11 Glückstrasse, Munich, Germany; per year, 20 marks.
Praktische Maschinen-Constructeur, Der—(*Pr. Msch. Cnstr.*), bi-weekly, Leipzig-Gohlis, Germany; per year, 16 marks.
Schweizerische Bauzeitung (*Schw. Bztg.*), German and French, 32 Brandschenkestrasse, Zurich.
Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins (*Ztsch. Oest.*), weekly.
Zeitschrift des Vereines Deutscher Ingenieure (*Ztsch. Ver. Ing.*), weekly, Berlin, Germany; per year, 32 marks.

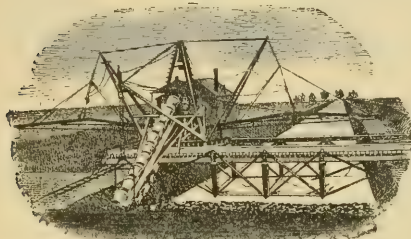
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- Am Arch.** *American Architect*, Boston; weekly.
- Am Eng & R R Jour.** *American Engineer & Railroad Journal*, New York; monthly.
- Am Mach.** *American Machinist*, New York; weekly.
- Am. W. W. Assn.** *Proceedings, American Water Works Association*, New York; annual.
- Annales des P & C.** *Annales des Ponts et Chaussées*, Paris, France; monthly.
- Arch f Eisenbw.** *Archiv für Eisenbahnwesen*, Berlin, Germany; bi-monthly.
- Bos. Jour. Com.** *Boston Journal of Commerce*, Boston, Mass.; weekly.
- Cassier.** *Cassier's Magazine*, New York; monthly.
- Civ Ing.** *Der Civilingenieur*; monthly.
- Deutsche Bztg.** *Deutsche Bauzeitung*, Berlin, Germany; semi-weekly.
- E & M Journal.** *Engineering and Mining Journal*, New York; weekly.
- Elec Eng.** *The Electrical Engineer*, New York; weekly.
- Elec Rev.** *Electrical Review*, London, Eng.; weekly.
- Elec World.** *The Electrical World*, New York; weekly.
- Eng Mag.** *The Engineering Magazine*, New York; monthly.
- Eng Mech.** *Engineering Mechanics*, Philadelphia, Pa.; monthly.
- Eng News.** *Engineering News*, New York; weekly.
- Eng Rec.** *Engineering Record*, New York; weekly.
- Eng Rev.** *Engineering Review*, London, Eng.; monthly.
- Ind Engng.** *Indian Engineering*, Calcutta, India; weekly.
- Ind. Engr.** *Indian Engineer*, Calcutta, India; weekly.
- Inland Arch.** *The Inland Architect and News Record*, Chicago, Ill.; monthly.
- Irrigation Age.** *The Irrigation Age*, Chicago, Ill.; monthly.
- Jour Assn Eng Soes.** *Journal of the Association of Engineering Societies*, Philadelphia; monthly.
- Jour f Gasb u Wasserv.** *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Germany; three times a month.
- Jour Frank Inst.** *Journal of the Franklin Institute*, Philadelphia, Pa.; monthly.
- Jour N E W W Assn.** *Journal of the New England Water Work Association*, New London, Conn. quarterly.
- Lon Eng.** *Engineering*, London, England; weekly.
- Lon Engineer.** *The Engineer*, London, England; weekly.
- Mst. Stm. Fitter.** *Master Steam Fitter*, Chicago, Ill.; monthly.
- Mech World.** *The Mechanical World*, Manchester, England; weekly.
- Mems Soc Ing Civ.** *Mémoires de la Société des Ingénieurs Civils*, Paris; monthly.
- Pav & Munic Eng.** *Paving and Municipal Engineering*, Indianapolis, Ind.; monthly.
- Power.** *Power*, New York; monthly.
- Pr Msch Constr.** *Der Praktische Maschinen-Constructeur*, Leipsic.
- Prac. Engr.** *Practical Engineer*, London; weekly.
- Proc Eng Club Phila.** *Proceedings of the Engineers' Club of Philadelphia*, Philadelphia, Pa.; quarterly.
- Proc Eng Soc W Pa.** *Proceedings of Engineers' Society of Western Pennsylvania*, Pittsburg, Pa.; monthly.
- Proc Inst C E.** *Proceedings of the Institution of Civil Engineers*, London, England
- Proc Inst Mech Engrs.** *Proceedings of the Institution of Mechanical Engineers*, London, England.
- Proc U S N I.** *Proceedings of the United States Naval Institute*, Annapolis, Md.; quarterly.
- R R Gaz.** *Railroad Gazette*, New York; weekly.
- Ry E & M.** *Railway Engineering and Mechanics*, Chicago, Ill.; monthly.
- Ry Eng.** *The Railway Engineer*, London, England; monthly.
- Sch Mines Quart.** *School of Mines Quarterly*, New York City.
- Schw Bztg.** *Schweizerische Bauzeitung*, Zurich; German and French; weekly.
- Sci Am Sup.** *Scientific American Supplement*, New York; weekly.
- Stone.** *Stone*, Chicago, Ill.; monthly.
- St Ry Gaz.** *The Street Railway Gazette*, Chicago, Ill.; weekly
- St Ry Jour.** *Street Railway Journal*, New York; monthly.
- St Ry Rev.** *Street Railway Review*, Chicago, Ill.; monthly.
- Sy Valve.** *Safety Valve*, New York; monthly.
- Tech Quart.** *Technology Quarterly and Proceedings of the Society of Arts*, Boston, Mass
- Trans A I E E.** *Transactions of the American Institute of Electrical Engineers*, New York City.
- Trans A I M E.** *Transactions of the American Institute of Mining Engineers*, New York.
- Trans A S C E.** *Transactions of the American Society of Civil Engineers*, New York; monthly.
- Trans A S M E.** *Transactions of the American Society of Mechanical Engineers*, New York
- Trans Can Soc C E.** *Transactions of the Canadian Society of Civil Engineers*, Montreal.
- Trans N A & M E.** *Transactions of the Society of Naval Architects and Marine Engineers*, Washington, D. C.; annual.
- Trans Tech Soc Pac C.** *Transactions of the Technical Society of the Pacific Coast*, San Francisco, Cal.
- Ztsch Oest.** *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins*; weekly.
- Ztsch Ver Ing.** *Zeitschrift des Vereins Deutscher Ingenieure*, Berlin, Germany; weekly.

For list of full titles, see page i.

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Experiments in —, by Hiram S. Maxim. Paper read before the Soc. of Arts. Illustrated. —Prac. Engr., Dec. 14, 1894, et seq.

AIR, Compressed —.

Its use for cold storage and cooling rooms in plants adapted to dwellings; advocated by G. D. Hiscox. —Sci. Am. Sup., Feb. 23, 1895.

AIR, Compressed —.

Size of piping for —, by Frank Richards. —Prac. Engr., Feb. 15, 1895.

AIR PUMPS.

Abstract of paper on the design of Air Pumps, by F. H. Bailey, U. S. N., from the Journal of the Am. Soc. of M. E. —Prac. Engr., Feb. 8, 1895.

ASPHALT, Tests of —.

How to determine its quality. Opinions from nearly a dozen cities, showing the necessity of chemical tests, and reporting that expert mechanical treatment is an equal necessity and that time in service is the only ultimate criterion. —Pav. and Munic. Eng., Feb. 1895.

BOILER Attendants.

Extracts from the "Instructions to Boiler Attendants," issued by The Manchester Steam Users' Association. —Am. Eng. & R. R. Jour., Jan., 1895.

BOILER and Engine.

Testing, by Chas. Day, London, Eng. —Prac. Engr., Dec. 7, 1894.

BREAKWATERS, Crib —.

See CRIB.

BRIDGE, Rolling Lifting —.

The Van Buren street — at Chicago; its peculiarities; electric operating machinery and details. Illustrated. —Eng. Rec., Feb. 16, 1895. St. Ry. Gaz., Feb. 16, 1895. R. R. Gaz., Feb. 15, 1895. Eng. News, Feb. 21, 1895.

BRIDGE WORKS.

Rules for draughting room work discussed at length. Chas. H. Wright. —Eng. News, Feb. 7, 1895.

BUILDING CONSTRUCTION.

The Manhattan Life Building in New York city and its quick construction. Foundation piers sunk 57 ft. to solid rock, and foundation completed within 6 months and super-structure in 8 months. Fully illustrated. Francis H. Kimball. —Eng. Mag., Feb., 1895.

BUILDINGS, Steel in —.

The construction of large buildings and the special adaptability and economy of the steel skeleton type. Address of C. T. Purdy before Boston Society of Civil Engineers. —Eng. Rec., Feb. 16, 1895, et. seq. (Abstract.)

BUILDING STONE, Testing —.

Resume of current methods of physical, chemical and microscopic tests, by F. Lynwood Garrison. —Stone, Feb., 1895.

CANAL LOCKS.

The Illinois and Mississippi Canal lock works extensively illustrated and described. The extensive use of concrete construction considered. Long and valuable article. —Eng. News, Feb. 14, 1895.

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CEMENT MORTAR.

Experiments showing that stamp sand with cement gives about one-third greater strength than standard quartz sand. —E. & M. Jour., Feb. 23, 1895.

CHIMNEYS and Draft.

Abstract of article from Helios, the publication of the Heine Boiler Co., on the draft of chimneys and their proportion. —Power, Feb., 1895.

CHUCK, Emery —.

A new chuck for emery cylinders. Illustrated. —Am. Mach., Feb. 21, 1895.

CIVIL ENGINEERS, the Institution of —.

History of its inception and growth, its constitution, membership and character. General illustrated description of buildings now to be erected for it. —Lon. Engineer, Jan. 18, 1895. Eng. Rec., Feb. 9, 1895. Sci. Am. Sup., Feb. 23, 1895.

COAL, Heat Value of —.

Abstract of paper by Wm. Forsyth, of the C., B. and Q. R. R., read before the Western Railway Club. The methods of determining the heat value of Western coals are discussed. —Ry. Eng. & Mech., Feb., 1895.

COLUMNS, Test of the Strength of —.

Abstract of paper by Gaetano Lanza and Edward F. Miller, read before the A. S. M. E. Results of 13 tests on spruce columns are given. —Ry. E. & M., Jan., 1895.

CONCRETE, Hydraulic —.

Materials may be so chosen as to require a less quantity of cement and so reduce cost. When so used the larger ingredients should be wet and mingled and the finer sand and concrete mixed dry and then incorporated with the larger. C. H. Platt. Eng. News, Feb. 21, 1895.

CONCRETE, Notes on —.

Percentage of voids in different materials and consequent proportions. The effect of a proportion of gravel or small stone to strengthen the product. Spencer B. Newberry. —Sci. Am. Sup., Feb. 9, 1895.

CONDUIT.

See ELECTRIC RAILWAY CONDUIT.

COPPER, Strength of —.

Experiments on the strength of copper. Paper by Prof. A. Martens, from Proc. Inst., C. E. —Prac. Engr., Feb. 8, 1895.

CRIB Breakwaters.

Their stability considered. The effect of the impact of wave action on the inner walls is much greater than on the outer. Its bearing on the probability of failure. —Eng. Rec., Feb. 23, 1895.

DAM and Weirs.

Modified form of the bear-trap dam as applied by Maj. W. A. Jones, at Sandy Lake, Minn. The application of the simple and inexpensive timber construction shown to be practicable for automatic quick-acting dams even with lock gates. —Eng. Rec., Feb. 2, 1895.

DAMS, Movable —.

American types and their development. Present practice in this country, and examples of their use. Lieut. Hiram M. Chittenden. —Eng. News, Feb. 7, 1895.

DRAFT SHEET for Locomotive.

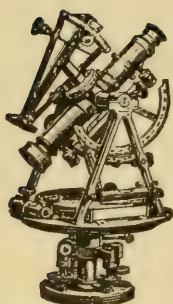
See LOCOMOTIVE.

DRAINAGE of the Zuyder Zee.

General plans and intended effects. —Lon. Eng., Jan. 18, 1895. Sci. Am. Sup., Feb. 16, 1895.

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DRILLING MACHINE.

Multiple-spindle drilling machine, made by Habersang & Zinzen, of Dusseldorf. Illustrated. —Am. Mach., Feb. 14, 1895.

DRILLS, Brandt's Rock —.

Rotary drills driven by hydraulic power to be used in the Simplon tunnel. The design of these drills illustrated. —Lon. Engineer, Jan. 25, 1895.

DROP HAMMERS.

Foundations for drop hammers, by Carl Norland. Illustrated. —Am. Mach., Feb. 14, 1895.

DYNAMO.

New Brush arc light machine. Illustrated. —Elec. Eng., Feb. 20, 1895.

DYNAMO and Engine.

The advantage of mounting the dynamo directly on the shaft of the engine. Present practice discussed. Illustrations of many engines so constructed. Thomas G. Smith, Jr. —Cassier, Feb., 1895.

DYNAMO.

Safety device for abnormal potential. Illustrated. —Elec. Eng., Feb. 6, 1895.

ELECTRIC CABLE RAILWAYS.

The advantage of electric power over any other for traction on inclined planes, as illustrated by the mountain railways of Burgenstock, Monte Salvatore and Stanserhorn, Switzerland. C. S. Du Riche Preller. —Lon. Eng., Feb. 1, 1895, et seq.

ELECTRIC Construction.

Cast iron, cast steel and wrought iron considered in connection with their usefulness for field magnet frames. Wrought iron recommended. Alton D. Adams. Discussion. —Trans. A. I. E. E., Jan. and Feb., 1895.

ELECTRIC Drills.

Canadian General Electric Percussion and Rotary Drills. —Illustrated. Elec. Eng., Jan. 20, 1895.

ELECTRIC-DRIVEN Machines.

The advantage of direct application by the motor of the power often amounting to an economy of 50 per cent. Illustrated. W. E. Hall. —Cassier, Feb., 1895.

ELECTRIC Furnace.

A novel electric furnace for heating iron ships. Illustrated. —Elec. Eng., Jan. 30, 1895.

ELECTRIC Lanterns.

The use of the electric light in lantern projection. Abstract of an illustrated lecture before the New York Electrical Society. —Elec. Eng., Jan. 30, 1895.

ELECTRIC LIGHT.

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ELECTRIC LIGHT Plant.

The municipal light plant at South Norwalk, Conn. —Elec. Eng., Jan. 30, 1895.

ELECTRIC LIGHT Plant.

The new plant of the Cleveland Electric Illuminating Co. Illustrated. —Elec. Eng., Feb. 20, 1895.

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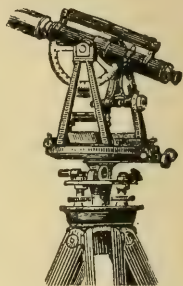
Three English plants —, the high pressure alternating system of Halifax and the low tension three-wire continuous current system, with accumulators, of Nottingham and Dewsbury. Well illustrated. —Elec. Rev., Feb. 1, 1895.

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ELECTRIC Lighthouse.

The temporary provision for light during installation, and the lens and electric equipment for Fire Island light at the New York harbor entrance. *Elec. World.*, Feb. 16, 1895.

ELECTRIC LIGHTING.

System to be used on the cars of the Brooklyn Bridge, New York, with details. *Illustrated. St. Ry. Gaz.*, Feb. 2, 1895.

ELECTRIC MOTOR.

Its advantages in the machine shop under various conditions. George Richmond. —*Eng. Rec.*, Feb. 16, 1894. *Eng. News*, Feb. 21 and 28, 1895.

ELECTRIC PLANT.

A storage battery electric railway and lighting plant. *Illustrated.* —*Eng. Mech.*, Feb., 1895.

ELECTRIC POWER.

Original cost and advantages considered in the application of — to isolated factories. Examples cited. Wm. A. Anthony. —*Eng. Mag.*, Feb. 1895.

ELECTRIC POWER.

Power consumed on electric railways, by G. Pellissier. —*St. Ry. Jour.*, Feb., 1895.

ELECTRIC POWER House.

Novel power house construction at Columbus, O., in which the central dome is utilized for the smoke stack by using forced draft. —*St. Ry. Jour.*, Feb., 1895.

ELECTRIC POWER Plant

at Niagara Falls. The elevator, power house wheel-pit, regulating apparatus, lubricating apparatus, 5000 H. P. alternators, rotary transformers and transformer house. —*Elec. World*, Feb. 9, 1895.

ELECTRIC POWER Station

of the Allegheny Traction Company. *Illustrated.* —*St. Ry. Jour.*, Feb., 1895.

ELECTRIC POWER Station.

Power stations of the Cleveland Electric Railway. *Illustrated.* —*Elec. Eng.*, Feb. 20, 1895.

ELECTRIC POWER Station.

System of the Binghamton Railway Co. *Illustrated.* —*St. Ry. Jour.*, Feb., 1895.

ELECTRIC RAILWAY.

The Siemens electric railway work at Hobart, Tasmania. *Illustrated.* —*Elec. Eng.*, Jan. 30, 1895.

ELECTRIC RAILWAY.

The supplementary wire for electric railway work, by Jno. C. Henry. —*Elec. Eng.*, Jan. 30, 1895.

ELECTRIC RAILWAY Conduit.

Electric conduit construction of the Metropolitan Street Railway Co., New York. —*St. Ry. Jour.*, Feb., 1895.

ELECTRIC RAILWAY Feeder Cable.

Practical notes on feeder cables for electric railways, by M. Ward Easby. —*St. Ry. Jour.*, Feb., 1895.

ELECTRIC RAILWAY Overhead Appliances.

Their strains and work considered in deducing sizes, shapes, dimensions and other characteristics necessary to secure a good equipment. A. G. Eneas. —*Elec. World*, Feb. 2, 1895.

ELECTRIC RAILWAY Overhead Construction.

Setting and construction of the iron poles, feed-line construction, insulation, &c., of the Chicago companies. *Illustrated.* —*St. Ry. Rev.*, Feb., 1895.

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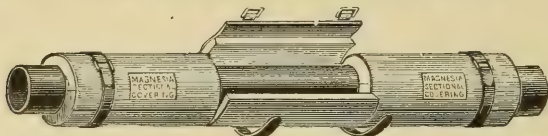
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INDEX TO CURRENT LITERATURE.

In this department is given an Index of current periodical engineering literature. To each title is appended a short note indicating the character of the article indexed. The index notes are printed on but one side of the paper, so that the titles may be cut out and pasted upon cards or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

All readers of the JOURNAL are requested to aid in making this Index as complete as possible. Notices for this department, and all matter to be indexed, should be sent to J. B. JOHNSON, Manager of Index Department, Washington University, St. Louis, Mo.

LIST OF PERIODICALS INDEXED.

Following the title of each periodical is given, in italics, the abbreviation by which it is referred to in the Index.

For alphabetical list of abbreviated titles, see page vii.

UNITED STATES.

ANNUAL.

- American Institute of Mining Engineers, Transactions of the** — (*Trans. A. I. M. E.*), 13 Burling Slip, New York; per year, \$5.
American Society of Mechanical Engineers, Transactions of the — (*Trans. A. S. M. E.*), 12 West Thirty-first Street, New York.
American Water Works Association, Proceedings of Annual Meetings of the — (*Am. W. W. Ass'n.*), 95 William Street, New York; per year, \$1.
Society of Naval Architects and Marine Engineers, Transactions of the—(*Trans. N. A. & M. E.*), W. L. Capps, Secretary, 1710 F Street N. W., Washington, D. C.; \$10 per annual volume.

QUARTERLY.

- Engineers' Club of Philadelphia, Proceedings of the** — (*Proc. Eng. Club Phila.*), 1122 Girard Street, Philadelphia, Pa.; per year, \$2.
New England Water Work Association, Journal of the — (*Jour. N. E. W. W. Assn.*), New London, Conn.; per year, \$2; single copies, 75 cents.
School of Mines Quarterly (*Sch. Mines Quart.*), Columbia College, New York City; per year, \$2; single copy, 50 cents.
Technology Quarterly and Proceedings of the Society of Arts (*Tech. Quart.*), Massachusetts Institute of Technology, Boston, Mass.; per year, \$3.
United States Naval Institute, Proceedings of the—(*Proc. U. S. N. I.*), United States Naval Institute, Annapolis, Md.; per year, \$3.50; single copy, \$1.

MONTHLY.

SOCIETIES.

- American Institute of Electrical Engineers, Transactions of the** — (*Trans. A. I. E. E.*), 12 West Thirty-first Street, New York City.
American Society of Civil Engineers, Transactions of the — (*Trans. A. S. C. E.*), 127 East Twenty-third Street, New York; per year, \$10.
Association of Engineering Societies, Journal of the — (*Jour. Assn. Eng. Socs.*), Philadelphia; per year \$3; single copy, 30 cents.
Engineers' Society of Western Pennsylvania, Proceedings of—(*Proc. Eng. Soc. W. Pa.*) Allegheny, Pa.; per year, \$7; single copy, 75 cents.
Franklin Institute, Journal of the — (*Jour. Frank. Inst.*), Franklin Institute, Philadelphia, Pa.; per year, \$5; single copy, 50 cents.

Continued on page iii

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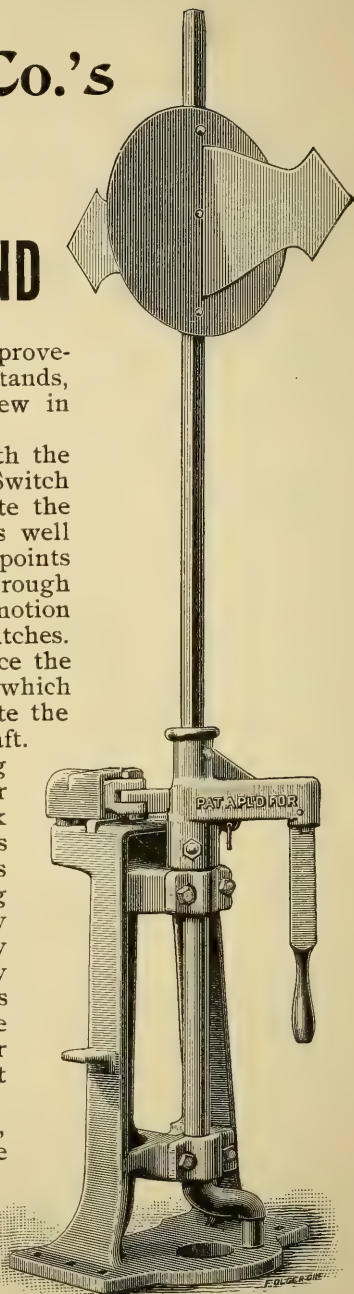
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List of Periodicals Indexed—Continued.

MONTHLY—Continued.

PERIODICALS.

- American Engineer and Railroad Journal** (*Am. Eng. & R. R. Jour.*), 47 Cedar Street, New York; per year, \$3; single copy, 25 cents.
- Cassier's Magazine** (*Cassier*), World Building, New York; per year, \$3; single copy, 25 cents.
- Clay Worker** (*Clay W.*), Indianapolis, Ind.; per year, \$2.00.
- Engineering Magazine** (*Eng. Mag.*), 47 Times Building, New York; per year, \$3; single copy, 25 cents.
- Engineering Mechanics** (*Eng. Mech.*), 430 Walnut Street, Philadelphia, Pa.; per year, \$1; single copy, 10 cents.
- Irrigation Age** (*Irrigation Age*), Chicago, Ill.; per year, \$2.
- Master Steam Fitter** (*Mst. Stm. Fitter*), 218 La Salle Street, Chicago, Ill.; per year, \$1; single copy, 10 cents.
- Municipality and County. The —** (*Munic & Co.*) Niagara Publishing Co., 202 Main St., Buffalo, N. Y.; per year, \$2.
- Paving and Municipal Engineering** (*Pav. & Munic. Eng.*), Municipal Engineering Co., 44 Chamber of Commerce, Indianapolis, Ind.; per year, \$2; single copy, 25 cents.
- Power** (*Power*), World Building, New York; per year, \$1; single copy, 10 cents.
- Railway Engineering and Mechanics** (*Ry. E. & M.*), 816 The Rookery, Chicago, Ill.; per year, \$1; single copy, 10 cents.
- Safety Valve** (*Sy. Valve*), 55 Liberty Street, New York; per year, \$1; single copy, 10 cents.
- Street Railway Journal** (*St. Ry. Jour.*), World Building, New York; per year, \$4; single copy, 35 cents.
- Stone** (*Stone*), Chicago; per year, \$2; single copy, 25 cents.
- Street Railway Review** (*St. Ry. Rev.*), 269 Dearborn Street, Chicago, Ill.; per year, \$2; single copy, 25 cents.

WEEKLY.

- American Architect** (*Am. Arch.*), Ticknor & Co.; 211 Tremont Street, Boston, Mass.; single copy, 15 cents.
- American Machinist** (*Am. Mach.*), 96 Fulton Street, New York; per year, \$2; single copy, 10 cents.
- Boston Journal of Commerce** (*Bos. Jour. Com.*), 128 Purchase Street, Boston, Mass.; per year, \$3; single copy, 6 cents.
- Electrical Engineer** (*Elec. Engr.*), 203 Broadway, New York; per year, \$3.
- Electrical World** (*Elec. World*), 177 Times Building, New York; per year, \$3; single copy, 10 cents.
- Engineering and Mining Journal** (*E. & M. Journal*), 253 Broadway, New York; per year, \$5; single copy, 15 cents.
- Engineering News** (*Eng. News*), Tribune Building, New York; per year, \$5; single copy, 15 cents.
- Engineering Record** (*Eng. Rec.*), 277 Pearl Street, New York; per year, \$5; single copy, 12 cents.
- Railroad Gazette** (*R. R. Gaz.*), 32 Park Place, New York; per year, \$4.20; single copy, 10 cents.
- Scientific American Supplement** (*Sci. Am. Sup.*), 361 Broadway, New York; per year, \$5; single copy, 10 cents.
- Street Railway Gazette** (*St. Ry. Gaz.*), Monadnock Block, Chicago; per year, \$3; single copy, 25 cents.

CANADA.

- Canadian Society of Civil Engineers, Transactions of the —** (*Trans. Can. Soc. C. E.*), McGill University, Montreal.

GREAT BRITAIN.

- Electrical Review** (*Elec. Rev.*), 22 Paternoster Row, London, E. C.; weekly; per year, 21s, 8d; single copy, 4d.
- Engineer, The —** (*Lon. Engineer*), London, England; weekly; per year, \$10; single copy, 25 cents.
- Engineering** (*Lon. Eng.*), London, England; weekly; per year, \$10; single copy, 25 cents.
- Engineering Review** (*Eng. Rev.*), 29 Great George Street, S. W., England; monthly; single copy, 6d.
- Institution of Civil Engineers, Proceedings of the —** (*Proc. Inst. C. E.*), 25 Great George Street, Westminster, S. W., London, England.

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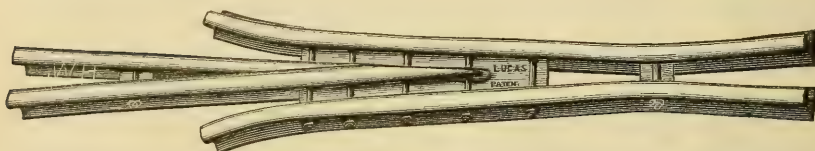
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List of Periodicals Indexed—Concluded.

WEEKLY.—Concluded.

Institution of Mechanical Engineers, Proceedings of the — (*Proc. Inst. Mech. Engs.*), 19 Victoria Street, Westminster, S. W., London, England.

Mechanical World (*Mech. World*), Manchester, England; weekly; per year, 8s, 8d.

Practical Engineer (*Prac. Engr.*), 2 Amen Corner, London, E. C., England; weekly; per year 10s.

Railway Engineer (*Ry. Eng.*), 8 Catherine Street, Strand, W. C., London, England; monthly; single copy, 1s

INDIA.

Indian Engineer (*Ind. Engr.*), Calcutta, India; per year, 20 Rs.

Indian Engineering (*Ind. Engng.*), Calcutta, India, weekly; per year, 18s; single copy, 8 annas.

FRANCE.

Ponts et Chaussees, Annales des — (*Annales des P. & C.*), monthly, Vve. Ch. Dunod, 49 Quai des Augustins, Paris, France.

Société des Ingenieurs Civils, Mémoires de la — (*Méms. Soc. Ing. Civils*), monthly, 10 Cité Rougement, Paris.

GERMANY, AUSTRIA AND SWITZERLAND.

Archiv für Eisenbahnwesen (*Arch. f. Eisenbw.*), bi-monthly, Julius Springer, Berlin, Germany; per year, 12 marks.

Civilingenieur, Der — (*Civ. Ing.*), monthly.

Deutsche Bauzeitung (*Deutsche Bztg.*), semi-weekly, Berlin, Germany; per year, 12 marks.

Journal für Gasbeleuchtung und Wasserversorgung (*Jour. f. Gasb. u. Wasserv.*), three times a month, 11 Glückstrasse, Munich, Germany; per year, 20 marks.

Praktische Maschinen-Constructeur, Der — (*Pr. Msch. Constr.*), bi-weekly, Leipzig-Gohlis, Germany; per year, 16 marks.

Schweizerische Bauzeitung (*Schw. Bztg.*), German and French, 32 Brandschenkestrasse, Zurich

Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins (*Ztsch. Oest.*), weekly.

Zeitschrift des Vereines Deutscher Ingenieure (*Ztsch. Ver. Ing.*), weekly, Berlin, Germany; per year, 32 marks.

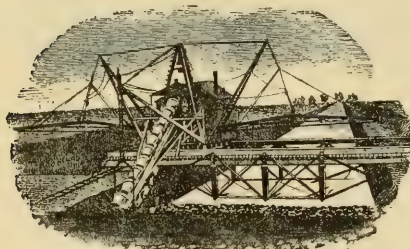
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OF PERIODICALS INDEXED.

For list of full titles, see page i.

- Am Arch.** *American Architect*, Boston; weekly.
- Am Eng & R R Jour.** *American Engineer & Railroad Journal*, New York; monthly.
- Am Mach.** *American Machinist*, New York; weekly.
- Am. W. W. Assn.** *Proceedings, American Water Works Association*, New York; annual.
- Annales des P & C.** *Annales des Ponts et Chaussées*, Paris, France; monthly.
- Arch f Eisenbw.** *Archiv für Eisenbahnwesen*, Berlin, Germany; bi-monthly.
- Bos. Jour. Com.** *Boston Journal of Commerce*, Boston, Mass.; weekly.
- Cassier.** *Cassier's Magazine*, New York; monthly.
- Civ Ing.** *Der Civilingenieur*; monthly.
- Clay W.** *Clay Worker*, Indianapolis, Ind.; monthly.
- Deutsche Bztg.** *Deutsche Bauzeitung*, Berlin, Germany; semi-weekly.
- E & M Journal.** *Engineering and Mining Journal*, New York; weekly.
- Elec Eng.** *The Electrical Engineer*, New York; weekly.
- Elec Rev.** *Electrical Review*, London, Eng.; weekly.
- Elec World.** *The Electrical World*, New York; weekly.
- Eng Mag.** *The Engineering Magazine*, New York; monthly.
- Eng Mech.** *Engineering Mechanics*, Philadelphia, Pa.; monthly.
- Eng News.** *Engineering News*, New York; weekly.
- Eng Rec.** *Engineering Record*, New York; weekly.
- Eng Rev.** *Engineering Review*, London, Eng.; monthly.
- Ind Engng.** *Indian Engineering*, Calcutta, India; weekly.
- Ind. Engr.** *Indian Engineer*, Calcutta, India; weekly.
- Irrigation Age.** *The Irrigation Age*, Chicago, Ill.; monthly.
- Jour Assn Eng Soes.** *Journal of the Association of Engineering Societies*, Philadelphia; monthly.
- Jour f Gasb u Wasserv.** *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Germany; three times a month.
- Jour Frank Inst.** *Journal of the Franklin Institute*, Philadelphia, Pa.; monthly.
- Jour N E W Assn.** *Journal of the New England Water Work Association*, New London, Conn. quarterly.
- Lon Eng.** *Engineering*, London, England; weekly.
- Lon Engineer.** *The Engineer*, London, England; weekly.
- Mst. Stm. Fitter.** *Master Steam Fitter*, Chicago, Ill.; monthly.
- Mech World.** *The Mechanical World*, Manchester, England; weekly.
- Mems Soc Ing Civ.** *Mémoires de la Société des Ingénieurs Civils*, Paris; monthly.
- Munic & Co.** *Municipality and County, The—*, Buffalo, N. Y.; monthly.
- Pav & Munic Eng.** *Paving and Municipal Engineering*, Indianapolis, Ind.; monthly.
- Power.** *Power*, New York; monthly.
- Pr Msch Constr.** *Der Praktische Maschinen-Constructeur*, Leipsic.
- Prac. Eng.** *Practical Engineer*, London; weekly.
- Proc Eng Club Phila.** *Proceedings of the Engineers' Club of Philadelphia*, Philadelphia, Pa.; quarterly.
- Proc Eng Soc W Pa.** *Proceedings of Engineers' Society of Western Pennsylvania*, Pittsburg, Pa.; monthly.
- Proc Inst C E.** *Proceedings of the Institution of Civil Engineers*, London, England
- Proc Inst Mech Engrs.** *Proceedings of the Institution of Mechanical Engineers*, London, England
- Proc U S N I.** *Proceedings of the United States Naval Institute*, Annapolis, Md.; quarterly.
- R R Gaz.** *Railroad Gazette*, New York; weekly.
- Ry E & M.** *Railway Engineering and Mechanics*, Chicago, Ill.; monthly.
- Ry Eng.** *The Railway Engineer*, London, England; monthly.
- Sch Mines Quart.** *School of Mines Quarterly*, New York City.
- Schw Bztg.** *Schweizerische Bauzeitung*, Zurich; German and French; weekly.
- Sci Am Sup.** *Scientific American Supplement*, New York; weekly.
- Stone.** *Stone*, Chicago, Ill.; monthly.
- St Ry Gaz.** *The Street Railway Gazette*, Chicago, Ill.; weekly
- St Ry Jour.** *Street Railway Journal*, New York; monthly.
- St Ry Rev.** *Street Railway Review*, Chicago, Ill.; monthly.
- Sy Valve.** *Safety Valve*, New York; monthly.
- Tech Quart.** *Technology Quarterly and Proceedings of the Society of Arts*, Boston, Mass
- Trans A I E E.** *Transactions of the American Institute of Electrical Engineers*, New York City.
- Trans A I M E.** *Transactions of the American Institute of Mining Engineers*, New York.
- Trans A S C E.** *Transactions of the American Society of Civil Engineers*, New York; monthly.
- Trans A S M E.** *Transactions of the American Society of Mechanical Engineers*, New York
- Trans Can Soc C E.** *Transactions of the Canadian Society of Civil Engineers*, Montreal.
- Trans N A & M E.** *Transactions of the Society of Naval Architects and Marine Engineers*, Washington, D. C.; annual.
- Ztsch Oest.** *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins*; weekly.
- Ztsch Ver Ing.** *Zeitschrift des Vereins Deutscher Ingenieure*, Berlin, Germany; weekly.

For list of full titles, see page i.

ENGINEERING NEWS

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For lists of periodicals indexed, see pages i and vii.

AIR-LIFT, Raising Water by the —.

The use of compressed air for raising water as applied by Dr. Pohle eleven years ago, and its development and present efficiency.—Eng. Rec., April 20, 1895, et seq.

ASPHALT Pavement Repairs.

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AXLES, Stresses in Car —.

Extended discussion, with application of deductions to the design of the axles.—R. R. Gaz., April 26, 1895.

BELT Transmission.

See POWER.

BELTING, Notes on —.

Rules to be observed in the use of belting so as to obtain the greatest economy of expenses. Fred W. Taylor.—Trans. A. S. M. E., Vol XV.

BOATS, Traction of —.

Conditions affecting resistance and cost, results of experience and different methods compared. W. H. Wheeler.—Lon. Engineer, April 12, 1895 et seq.

BOILERS, Corrosion of Tubes of —.

A physical explanation of the rapid corrosion of steel boiler tubes, by W. H. Gibbons, President Parkesburg Iron Co.—Am. Eng. & R. R. Jour., April, 1895.

BOILERS, Corrosion of —.

See CORROSION.

BOILERS, Deterioration of Locomotive and Marine — Due to Expansion.

Article by Herr Lentz, with suggestions for lessening the deterioration.—Am. Eng. & R. R. Jour., March, 1895, et seq.

BOILERS, Settings for —.

Illustrated description of boiler setting, for return tubular boilers, adopted by the Hartford Steam Boiler Inspection and Insurance Co.—Eng. Mech., April, 1895.

BOILERS, Types of Water-Tube —.

An illustrated article giving cuts and short description of different forms of water-tube boilers.—Am. Eng. & R. R. Jour., April, 1895, et seq.

BRAKE, New Form of Prong —.

Illustrated description of form of brake devised by R. C. Carpenter.—Trans. A. S. M. E., Vol. XV.

BRICK Making.

Methods of improving quality. The use of brick machines and work in brick kilns. J. W. Crary, Sr.—Clay W., Feb., 1895.

BRIDGE Across the Rhine at Bonn.

An article by A. Zschetzche, describing the various designs submitted in competition for this new bridge. The article is well illustrated and shows very handsome designs and also very interesting details.—Ztsch. Ver. Ing., March 30, 1895, et seq.

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BRIDGE, Delaware River —.

The new bridge of the Pennsylvania R. R. at Philadelphia. Three main spans of 533 feet length and one draw span of 330 feet. Illustrated. Characteristic features of the specifications. —R. R. Gaz., April 5, 1895.

BRIDGE, Expansion Bearings for — Superstructures.

By Geb. S. Morison. Trans. A. S. M. E., Vol. XV.

BRIDGE Floor of Concrete and Wire.

Details of construction of Lincoln Park bridge, Chicago. Illustrated. —Eng. News, April 4, 1895.

BRIDGE, Rolling Lift —.

The Van Buren street bridge at Chicago. Its peculiarities, electric operating machinery and details. Illustrated. —St. Ry. Rev., March, 1895.

BRIDGES, Country Road —.

General considerations and suggestions. C. C. Wentworth. —Jour. Assn. Eng. Socs., March, 1895.

BRIDGES, Field Inspection of —.

Details to be considered in bridge erection. Harold Jeans. —R. R. Gaz., April 5, 1895.

BRIDGES, Soft Steel for —.

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BRIDGES, The Erection of —.

Different methods and their applicability, by Chas. H. Wright. Illustrated. —Eng. News, April 25, 1895.

BUILDING CONSTRUCTION, Steel in —.

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BUILDING ERECTION, Regulations Governing —.

Adapted to cities having a population of from 10,000 to 30,000 and adopted by Roanoke, Va. —Jour. Assn. Eng. Socs., March, 1895.

CABLES for Street Railways.

Construction and strength of — by R. J. McCarthy. Illustrated. —St. Ry. Jour., April, 1895.

CANAL, The Chicago Sanitary District —.

First paper of the series, giving an introductory and general statement of its purposes, route and control by legislation and the administrative board. By Isham Randolph, chief engineer. —Jour. Assn. Eng. Socs., March, 1895.

CANAL LOCKS, The North Baltic —.

Concrete foundation, masonry walls and machine-worked gates of the locks at Holtenau. Illustrated. —Eng. Rec., April 27, 1895.

CANAL Lock.

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CHIMNEYS, Large —.

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COAL, Use of Small Sizes of Anthracite for Generating Steam.

Methods for determining size, specific gravity, moisture, etc. Eckley B. Cox. —Trans. A. S. M. E., Vol. XV.

COAL MINE Surface Works.

The North Staffordshire, England, mines, and details of surface machinery and works whereby cost of labor at surface is reduced to one-twelfth of total expenses for labor. Edward Brownfield Wain. Discussion. —Proc. Inst. C. E., Vol. 119.

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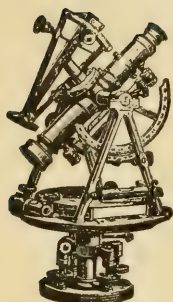
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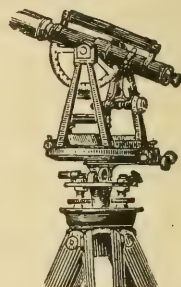
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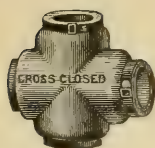
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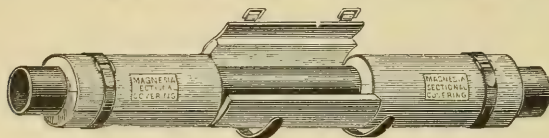
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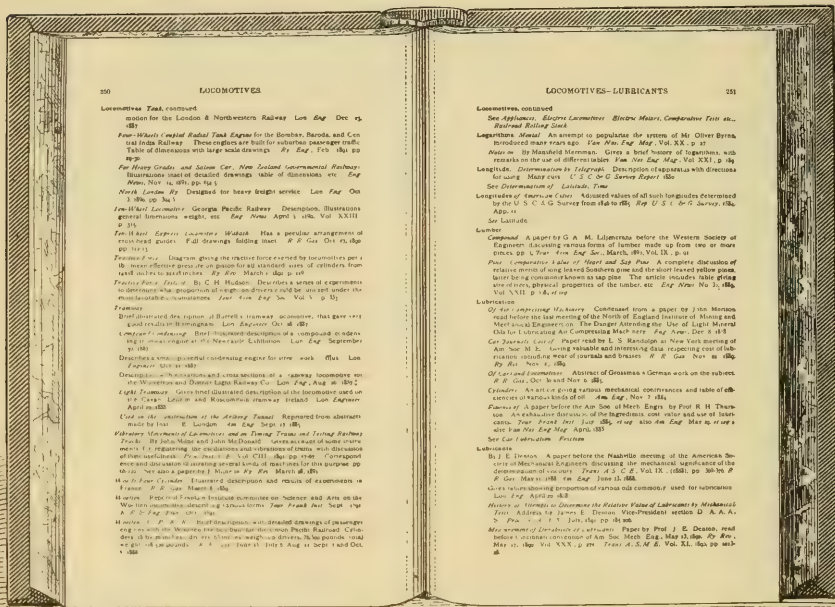
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Examples and data additional to those published by the same writer last year. Prof. William D. Pence. —Eng. News, April 25, 1895.

STEAM, Plants for — Power.

An article discussing forced draft and atmospheric condensing for steam power plants. —Eng. Mech., April, 1895.

STEAM-ENGINE, Contemporary Economy of the —.

A paper by R. H. Thurston showing how close the efficiency of the actual engine now approaches the computed efficiency of the ideal thermodynamic engine. —Trans. A. S. M. E., Vol. XV.

STEAM-ENGINE, The Economy of the —.

A determination of the effect on the economy of the steam engine of water in the steam. By R. C. Carpenter. —Trans. A. S. M. E., Vol. XV.

STEEL in Large Buildings.

Historical review and general discussion of the use of steel and its efficiency, and problems occurring in its adaptation to great buildings. C. T. Purdy. —Jour. Assn. Eng. Socs., March, 1895. Abstract, Eng. Rec., February 16, 1895, et seq.

STEEL, Progress in the Manufacture of — Castings.

By H. L. Jautt. —Trans. A. S. M. E., Vol. XV.

STEEL, Soft — for Bridges.

Its use, necessary qualities and suggested specifications, with tables giving steel requirements of 27 railroads and bridge authorities. Illustrated. Harry J. Lewis. —Eng. News, April 25, 1895. Abstract, Eng. Rec., April 27, 1895.

STREET Cleaning.

Cost and conditions for twelve American cities. —Eng. News, April 11, 1895.

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General consideration, with illustrations drawn from the experience of Buffalo, N. Y. —Municipality & County, April, 1895.

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Specifications used for Oswego, N. Y., as prepared by William Pierson Judson, securing the rate of \$81 per lamp per year. —Eng. News., April 11, 1895.

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Cable street railway system of the Columbia Railway, Washington, D. C. Illustrated. —St. Ry. Jour., April, 1895.

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STREET RAILWAYS and Suburban Railways in Italy.

Their great development in Northern Italy, with description of roads, rolling stock and maintenance. Maps and illustrations. P. Amoretti. —Proc. Inst. C. E., Vol. 119. Lon. Engineer, March 22, 1895, et seq.

STREET RAILWAY WHEELS.

Comparison of the merits of different kinds of wheels for street railways. —St. Ry. Jour., April, 1895.

STREET SPRINKLING.

See WATER WORKS ASSOCIATION.

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An approximate triangulation method described by Walter G. Kirkpatrick. —Papers of Eng. Assn. of the South, August, 1894.

SURVEYS of Rivers by Stadia.

The extension of the stadia system to the location of soundings, securing increased efficiency, economy and frequently greater accuracy. J. L. Van Ornum. —Jour. Assn. Eng. Socs., March, 1895. Abstract, Eng. Rec., Feb. 9, 1895.

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TESTS of Paving Brick.

See PAVING BRICK.

TIMBER Preservation.

The creosote process as applied to ties in France. —R. R. Gaz., April 5, 1895.

TRACTION of Boats.

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TRAINS, Resistance of —.

Results of experiments made by Mons. Du Bousquet to determine the resistance of trains at different speeds and on different grades. —Ry. E. & M., April, 1895.

TRUSSES, Stresses in —.

Illustrated article by Malverd A. Howe, showing method of determining maximum moments and shears, in trusses with parallel chords, by graphics. —Eng. Mech., April, 1895.

TURBINE, The Pelton.

Article describing and illustrating various installations of this class of turbines. The illustrations are very good and show many details. —Prktsch. Msch. Knstr., March 28, et seq.

UNDERPINNING a Heavy Foundation.

The constantly settling High Court Buildings of Calcutta, India, underpinned by driving horizontal piles beneath the foundations. —Ind. Engng., Dec. 29, 1894. Eng. News, April 4, 1895.

VALVES, Proportions and Movement of Slide —.

A paper by W. D. Wansbrough. —Mech. World, March 22, 1895, et seq.

VALVE-GEAR, The "Buckeye" —.

A detailed description of the valve-gear used by the Buckeye Engine Co., by Albert K. Mansfield. —Trans. A. S. M. E., Vol. XV.

VIADUCT, The Pecos —.

Valuable account of this important work for improving the alignment of the G. H. & S. A. R. R. in Texas. This viaduct is one of the boldest yet built, being 2180 ft. long and 321 ft. above water. Fully illustrated. Julius Kruttschnitt. —Papers of Eng. Assn. of the South, Aug., 1894.

WATER Measurement.

Report to Montana Society of Engineers by A. M. Rybn, recommending that water be measured only in terms of cubic feet per second; and that in adjusting claims where the miner's inch has been the unit, one cubic foot per second be taken as equivalent to 40 miner's inches. —Jour Assn. Eng. Socs., Jan., 1895. Eng. News, April 11, 1895.

WATER POWERS of the Western States.

The great field unoccupied, and some of the utilized water powers. Plants at Gothenburg, Kearney, Ouray, Aspen and other places. Illustrated. A. G. Allan. —Eng. Mag., April, 1895.

WATER POWER, Niagara —.

See WATER WORKS ASSOCIATION.

WATER Rights in Wyoming.

Their determination and limitations, record of work done in 1893-4 by the State Engineer, problems and rulings of the State Board of Control, statement of unused land and water of the State, and recommended laws and rules. Valuable and useful report showing the progress on these questions. Elwood Mead. —Report of State Engineer of Wyoming, 1894.

WATER SUPPLY.

A graphical method of representing adequacy of supply for the demand in any given set of conditions. Illustrative diagram. James L. Greenleaf. —Eng. News, April 11, 1895.

WATER SUPPLY Conduit.

The new steel and masonry conduit of Rochester, N. Y. Full and valuable details of pipe and the laying, with gate house, air valves, blow-offs and the new japanning process used in a part of the pipe. Illustrated. —Eng. News, April 11, 1895.

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WATER SUPPLY of Belfast, Ireland.

Report of the water commissioners on seven possible sources, and selection of the Mourne Mountains, which are about forty miles from Belfast. — Lon. Engineer, March 22, 1895.

WATER SUPPLY, Purity of —.

The growth of diatoms in ponds and reservoirs and their causes. Deeper bodies of water seem to have two distinct seasons of rapid growth—spring and autumn—when occurs a vertical circulation of the water, and the presence of air and nitrates favor the growth. A result of investigations favors removal of surface soils from reservoir sites. George C. Whipple. — Tech. Quart., Oct., 1894.

WATER SUPPLY.

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WATER WORKS and Electric Lighting.

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WATER WORKS at Bombay, India.

The Rajkot works, recently completed. R. B. Booth. — Proc. Inst. C. E., Vol. 119.

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The present system, including new and important additions. Full and interesting description, with details of new construction, that of the new conduit being of especial interest and value. Illustrated. By Emil Kinchling, chief engineer. — Eng. Rec., April 13, 1895, et seq.

WATER WORKS, Some New —.

Article by E. Josse, describing some modern waterworks, especially the engines and pumps for which excellent detail drawings are given. The pumps shown are of the most modern type. — Ztsch. Ver. Ing., March 30, 1895, et seq.

WATER WORKS.

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WATER WORKS ASSOCIATION, Convention of the American —.

Papers read on Niagara Water Power; Water Supply and Fire Protection of the World's Columbian Exposition; Kansas City case continued; Filtration; Damage for Appropriation of Streams; Wells and Water Supply, New Utrecht, N. Y.; Analysis of Public Water Supplies; The Prevention of Electrolysis of Water Mains and Service Pipes; Methods of Street Sprinkling, and Cost; Proposed Filtration and Purification of Mississippi River Water for Minneapolis; Fire Protection Lines; Private Water Companies; Province of Ontario; Electrolysis, Experience and Opinions; Electrolysis vs. Water Works Systems. — Proceedings Am. Water Works Assn, 1894.

WINDMILLS for Raising Water.

Theoretical considerations and description of different types. J. A. Griffiths. — Proc. Inst., C. E. Vol. 119.

WOOD, Preservation of —.

The portable plant of the Southern Heywood. and the method of creosoting used at the Oakland Works. W. G. Curtis. — R. R. Gaz., Feb. 8, 1895. Sci. Am. Sup., April 13, 1895. Eng. News, April 4, 1895.

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CANADA.

- Canadian Society of Civil Engineers, Transactions of the —** (*Trans. Can. Soc. C. E.*), McGill University, Montreal.

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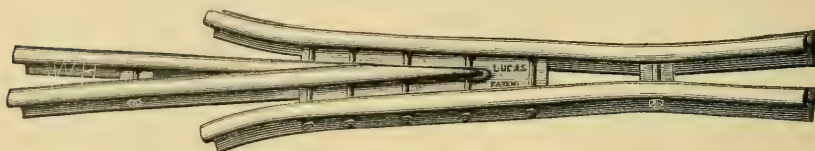
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Schweizerische Bauzeitung (*Schw. Bztg.*), German and French, 32 Brandschenkestrasse, Zurich.

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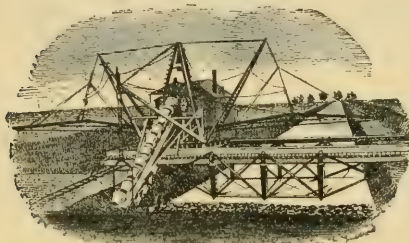
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Am. W. W. Assn. *Proceedings, American Water Works Association*, New York; annual.
Annales des P & C. *Annales des Ponts et Chaussées*, Paris, France; monthly.
Arch f Eisenbw. *Archiv für Eisenbahnwesen*, Berlin, Germany; bi-monthly.
Bos. Jour. Com. *Boston Journal of Commerce*, Boston, Mass.; weekly.
Cassier. *Cassier's Magazine*, New York; monthly.
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Jour N E W Assn. *Journal of the New England Water Work Association*, New London, Conn. quarterly.
Lon Eng. *Engineering*, London, England; weekly.
Lon Engineer. *The Engineer*, London, England; weekly.
Mst. Stm. Fitter. *Master Steam Fitter*, Chicago, Ill.; monthly.
Mech World. *The Mechanical World*, Manchester, England; weekly.
Mems Soc Ing Civ. *Mémoires de la Société des Ingénieurs Civils*, Paris; monthly.
Munic & Co. *Municipality and County, The—*, Buffalo, N. Y.; monthly.
Pav & Munic Eng. *Paving and Municipal Engineering*, Indianapolis, Ind.; monthly.
Power. *Power*, New York; monthly.
Pr Msch Constr. *Der Praktische Maschinen-Constructeur*, Leipsic.
Prac. Engr. *Practical Engineer*, London; weekly.
Proc Eng Club Phila. *Proceedings of the Engineers' Club of Philadelphia*, Philadelphia, Pa.; quarterly.
Proc Eng Soc W Pa. *Proceedings of Engineers' Society of Western Pennsylvania*, Pittsburgh, Pa.; monthly.
Proc Inst C E. *Proceedings of the Institution of Civil Engineers*, London, England.
Proc Inst Mech Engrs. *Proceedings of the Institution of Mechanical Engineers*, London, England.
Proc U S N I. *Proceedings of the United States Naval Institute*, Annapolis, Md.; quarterly.
R R Gaz. *Railroad Gazette*, New York; weekly.
Ry E & M. *Railway Engineering and Mechanics*, Chicago, Ill.; monthly.
Ry Eng. *The Railway Engineer*, London, England; monthly.
Sch Mines Quart. *School of Mines Quarterly*, New York City.
Schw Bztg. *Schweizerische Bauzeitung*, Zurich; German and French; weekly.
Sci Am Sup. *Scientific American Supplement*, New York; weekly.
Stone. *Stone*, Chicago, Ill.; monthly.
St Ry Gaz. *The Street Railway Gazette*, Chicago, Ill.; weekly.
St Ry Jour. *Street Railway Journal*, New York; monthly.
St Ry Rev. *Street Railway Review*, Chicago, Ill.; monthly.
Sy Valve. *Safety Valve*, New York; monthly.
Tech Quart. *Technology Quarterly and Proceedings of the Society of Arts*, Boston, Mass.
Trans A I E E. *Transactions of the American Institute of Electrical Engineers*, New York City.
Trans A I M E. *Transactions of the American Institute of Mining Engineers*, New York.
Trans A S C E. *Transactions of the American Society of Civil Engineers*, New York; monthly.
Trans A S M E. *Transactions of the American Society of Mechanical Engineers*, New York.
Trans Can Soc C E. *Transactions of the Canadian Society of Civil Engineers*, Montreal.
Trans N A & M E. *Transactions of the Society of Naval Architects and Marine Engineers*, Washington, D. C.; annual.
Ztsch Oest. *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins*; weekly.
Ztsch Ver Ing. *Zeitschrift des Vereins Deutscher Ingenieure*, Berlin, Germany; weekly.

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Extended serial discussion of past developments, present uses and future probabilities. J. C. Howell.—Elec. Rev., May 24, 1895, p. 660, et seq.

AERIAL NAVIGATION.

Article by A. Ritter, describing the progress made in this line during the last few years.—Ztsch. Ver. Ing., May 18, 1895.

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Description and details of the New York Air Brake Co.'s machine. Illustrated.—Eng. News, June 6, 1895, p. 374.

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Its proposed extension, with reasons.—Eug. News, May 30, 1895, p. 351.

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By W. H. Booth. Illustrated.—Prac. Eng., May 24, 1895, p. 400.

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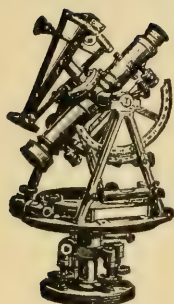
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General review of the Croton watershed system, with location of dam, plan, sections and general description of this dam which forms one of the Croton series. Illustrated serial. —Eng. Rec., June 22, 1895, p. 58, et seq.

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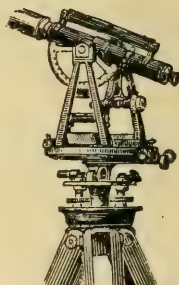
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Boiler and engine rooms, multipolar generator and other equipment of the Syracuse Street Railroad Co. Illustrated.—St. Ry. Rev., June, 1895, p. 358.

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Their advantage in certain small works, or as auxiliary engines and otherwise. Their use at Carlsruhe, Leer, Truen, Gottingen, Meissen, Munster, Rothenberg and other German cities. Illustrated.—Eng. Rec., June 1, 1895, p. 4.

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Plans and specifications. Illustrated.—Eng. Rec., June 22, 1895, p. 61.

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An article describing and illustrating a new hydraulic press for shaping boiler plates.—Prktsch. Msch. Cnstr., April 25, 1895.

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An article by E. Glinzer describing this new lamp, but especially giving the previous work in that line. The article also discusses the manner of manufacture of the lamp.—Jour. F. Gasb. u. Wasserv. May 11, 1895, et seq.

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Historical review of the blast furnace in the U. S., showing the great progress made. John Birkenbine. Illustrated. —Eng. Mag., Vol. IX, No 3 (1895), p. 483.

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Comparative merit of iron oxide and lead paints. Correspondence between Ralph K. Wing and E. Gerber. —Eng. News, May 30, 1895, p. 355.

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The English code adopted by the principal railroads as issued by the London and Northwestern R. R. —R. R. Gaz., June 14, 1895, p. 386.

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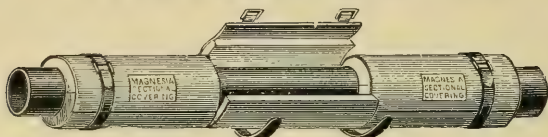
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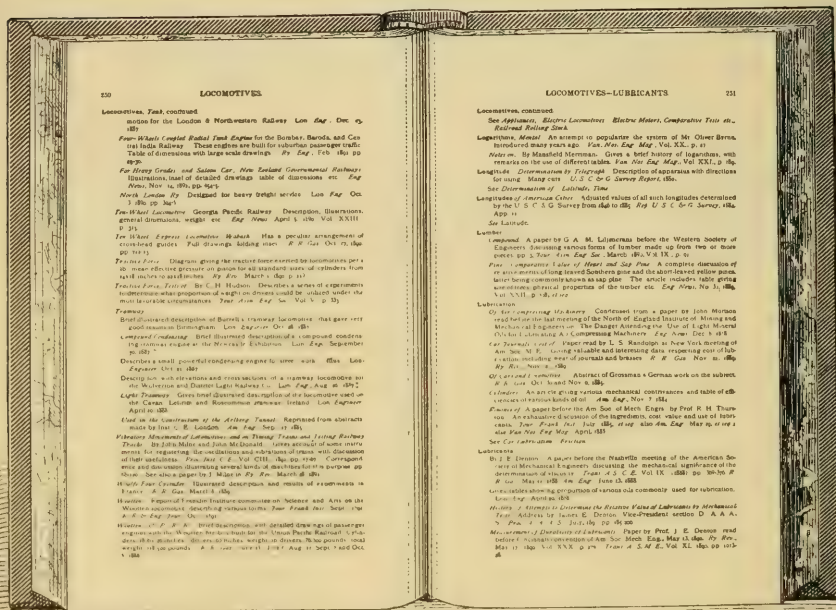
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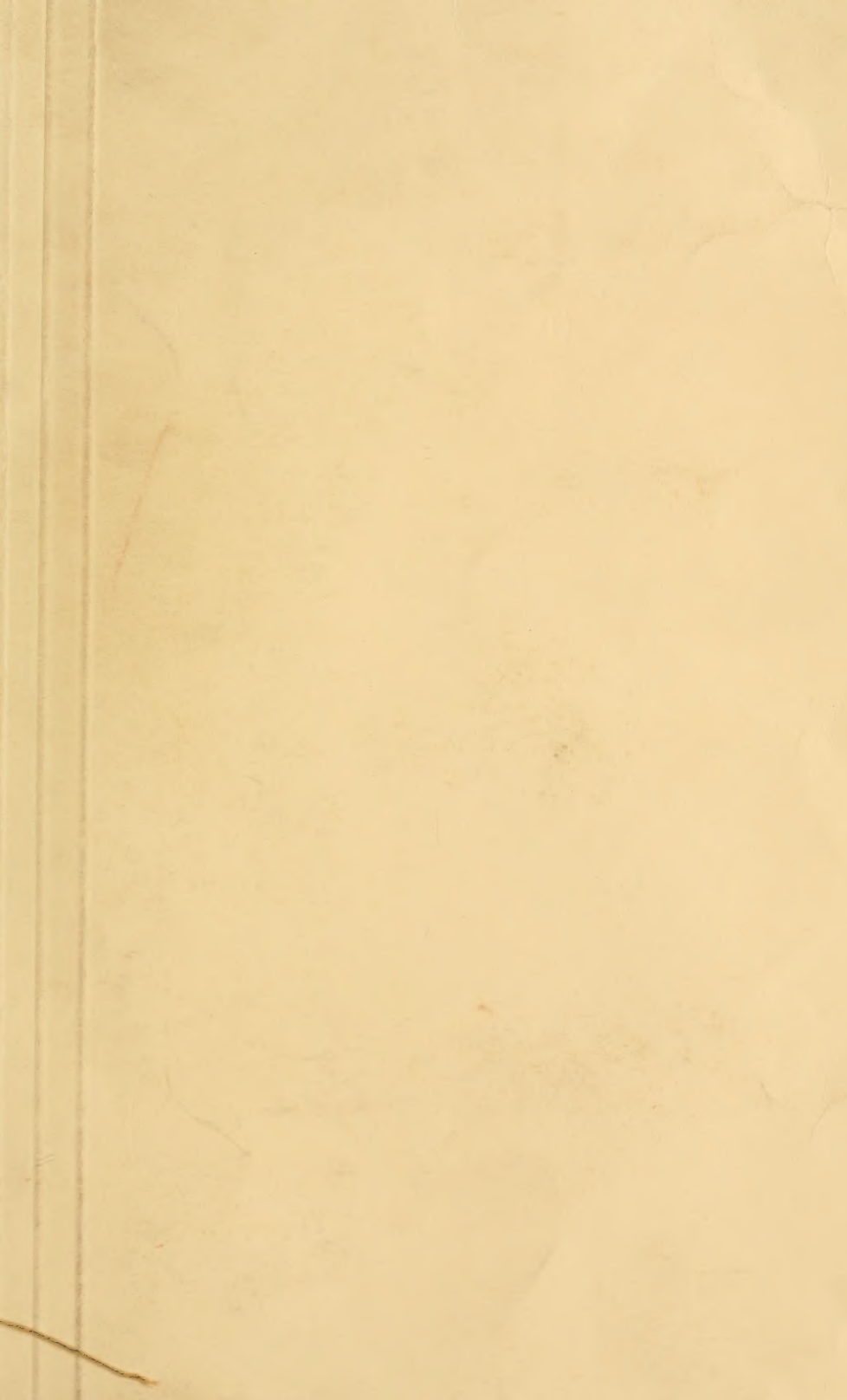
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